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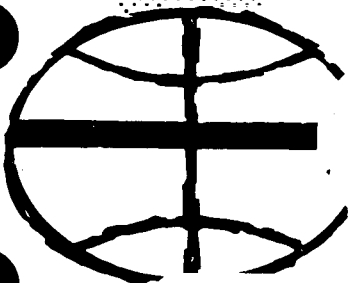
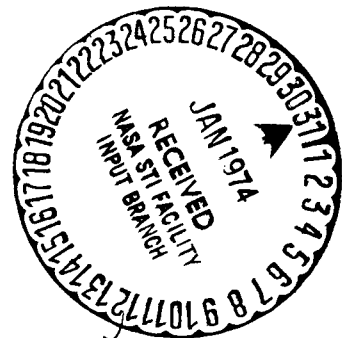
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-113

OPERATIONAL SPACECRAFT ATTITUDE SEQUENCE FOR MISSION F

April 23, 1969

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PROJECT APOLLO
OPERATIONAL SPACECRAFT ATTITUDE SEQUENCE FOR
MISSION F

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April 23, 1969

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OPERATIONAL SPACECRAFT ATTITUDE SEQUENCE FOR MISSION F

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1. SUMMARY AND INTRODUCTION

1.1 General

This document contains the operational spacecraft attitude sequence for mission F. The purpose of the document is to provide a source of spacecraft (command and service module (CSM) and lunar module (LM)) attitude data for the nominal cislunar and lunar orbit mission operations. Changes and revisions to the preliminary F mission attitude sequence, Reference 1, have been incorporated in order to present the latest possible mission planning inputs. These updates include the May 18 launch date with the extended lunar orbit stay time, the approach azimuth change to duplicate the lunar landing mission (mission G) ground track, and the recommended landmark tracking procedures.

Cislunar and lunar orbit data for the spacecraft operational attitude sequence are presented in the following format:

1. Discussion of the major attitude events occurring in the mission
2. Figures illustrating the spacecraft attitude events and activities
3. An attitude timeline listing the chronological sequence of events (Table I). Mission event times were obtained from the Apollo 10 Final Flight Plan, Reference 2.
4. Tabular data summarizing the pertinent spacecraft attitude and orbital parameters (Table II)

1.2 Trajectory Profile

The CSM and LM state vector and ephemeris data for generating the CSM solo, LM ascent propulsion system (APS) burn to depletion, and

docked CSM/LM attitude data were obtained from the Lunar Mission Analysis Branch of MPAD-MS. The lunar orbit rendezvous trajectory parameters were furnished by the Orbital Mission Analysis Branch of MPAD-MS. The mission trajectory profile from earth parking orbit insertion to entry at 400,000 feet altitude was precision integrated by the Apollo Reference Mission Program, Version ARM06. Launch date for the mission is May 18, 1968 at 11:48:35.3 Eastern Standard Time with a 72-degree launch azimuth and a Pacific translunar injection (TLI) on the first opportunity.

Translunar and transearth flight times are approximately 73 hours and 53 hours, respectively. The lunar orbit phase consists of 31 revolutions (approximately 62 hours) in lunar orbit devoted primarily to LM testing in the lunar environment and lunar landmark tracking.

1.3 Attitude Data Generation

The ARM06 program was used in producing the CSM and LM attitude data required to define the nominal mission attitude timeline. For the program simulation, instantaneous maneuvers were assumed in reorienting the spacecraft from an existing attitude. Appropriate time intervals are provided for finite reorientations in the timeline. The maneuver times are representative only and are not intended to reflect actual rates.

In addition to the spacecraft attitude data supplied by this document, computer tapes of the mission trajectory and attitude profile are available. Requests for these tapes should be made through the Mission Planning Support Office of MPAD-MS.

1.4 Spacecraft Attitude Constraints

The CSM and LM, both in the docked and undocked configurations, are subject to attitude restrictions throughout the mission. In general, these restrictions are imposed by subsystem requirements, mission requirements, or geometry limitations.

The major constraints considered in defining the F mission spacecraft attitude timeline are enumerated below. Unless noted otherwise, the constraints are relevant to specific events or operations. Violation of any constraint is noted in the attitude timeline discussion (Sections 3, 4, 5, and 6).

1. Earth Orbit and Cislunar Phases

a. The S-IVB/SLA/CSM/LM configuration in earth orbit coast should maintain a local horizontal attitude hold with the CSM plus X-axis forward along the direction of motion and the crew heads down (CSM minus

Z-axis towards the earth). This local attitude hold should be established following parking orbit insertion and maintained until just prior to the translunar injection burn.

b. CSM tracking, telemetry, and voice are required during transposition, docking, and ejection.

c. CSM tracking, command, telemetry, and voice are required for 1 hour following ejection.

d. CSM inertial measurement unit (IMU) gimbal lock must be avoided for all events and operations in the cislunar phase. For the F mission, IMU gimbal lock is assumed to occur when the angle between the outer and inner gimbal axes is less than 45 degrees.

e. During docking with no artificial lighting, the sun must lie between 90 and 150 degrees of the CSM positive X-axis.

f. Pitch and roll maneuvers required for transposition and docking are performed at 5 degrees per second.

g. CSM monitoring of the S-IVB is required for 1 hour following ejection.

h. During passive thermal control (PTC) the angle between the line of sight to the sun and the CSM Y-Z plane must be less than 20 degrees. A roll rate between one and two and a half revolutions per hour must also be maintained.

i. A ratio of a least 5 to 1 should be maintained between periods of PTC and attitude holds. The maximum length of a continuous attitude hold should not exceed 3 hours during translunar coast and 2 hours during transearth coast.

2. Lunar Orbit Phase

a. CSM and LM gimbal lock must be avoided for all events and operations in the lunar orbit phase. For the F mission, IMU gimbal lock is assumed to occur when the angle between the outer and inner gimbal axes is less than 45 degrees.

b. CSM and LM high-gain communications are highly desirable when earth line of sight exists and the attitude does not conflict with other mission objectives.

c. During the sleep period prior to LM undocking, the CSM/LM docked attitude must provide MSFN coverage through the CSM S-band steerable antenna when earth line of sight exists. A nominal thermal environment must also be provided for the CSM RCS quads by orienting the spacecraft with respect to the sun and lunar surface.

d. CSM and LM IMU alignments in lunar orbit must avoid sunlight interference. For the F mission, this is accomplished by scheduling these events to occur in darkness. During the alignment operation, the spacecraft attitude must provide the sextant (SXT) field of coverage with at least two reference stars from 20 to 90 degrees apart. The shaft drive axis (SDA) must be at least 20 degrees above the lunar horizon.

e. During undocked activities, CSM and LM attitudes should be favorable for VHF communications unless precluded by other requirements.

f. During CSM landmark tracking, the actual marking operation should be confined to the portion of the orbit above 35 degrees elevation angle with respect to the landmark. The CSM attitude and attitude rate should be established to allow maximum optics coverage during this time. Due to an optics system constraint, the CSM attitude rate while marking is limited to a rate less than $2/3$ degree per second.

g. LM inspection by the CSM must be made in sunlight as soon as possible after undocking.

h. Tracking periods during undocked activities specify a line of sight be maintained between the vehicles which satisfies the respective tracking requirements of each. The initial tracking attitude for the CSM and LM should be heads down and heads up, respectively.

i. For the CSM-LM docking maneuver performed in sunlight, the angle between the minus X-axis of the active vehicle and the sun should not be greater than 90 degrees to avoid glare interference to the active vehicle.

j. During terminal rendezvous and docking, at ranges greater than 50 feet the LM attitude must provide CSM visibility through the LM forward (plus Z) windows. After pitchover to the docking orientation at a range of 50 feet, CSM visibility is required through the overhead (plus X) window.

k. From the LM jettison maneuver after docking to the LM APS burn to depletion, the CSM attitude should permit visual monitoring of the LM to confirm adequate separation.

l. The LM inertial APS burn to depletion attitude should provide MSFN coverage of the burn through the LM S-band steerable antenna.

m. At LM jettison, the burn for the CSM evasive maneuver must place the CSM above and behind the LM at APS ignition.

Further detail on lunar mission attitude constraints may be obtained from Reference 3. Information concerning CSM/LM docked high-gain communications is found in Reference 4.

2. SYMBOLS

AGS	abort guidance system
ALT	altitude
AOT	alignment optical telescope
APS	ascent propulsion subsystem
ARM06	Apollo Reference Mission Program, Version ARM06
CDH	constant delta altitude
CM	command module
CMP	command module pilot
COAS	crew optical alignment sight
CP	control point
CPA	closest point of approach
CSI	coelliptic sequence initiation
CSM	command and service module
DOI	descent orbit insertion
DPS	descent propulsion subsystem
g. e. t.	ground elapsed time (hr:min:sec)
G&N	guidance and navigation
HGA	high-gain antenna
IGA	inner gimbal angle
IMU	inertial measurement unit
IP	initial point
LAT	selenographic latitude
LM	lunar module
LOI-1	first lunar orbit insertion burn
LOI-2	lunar orbit circularization burn

LON	selenographic longitude
LR	landing radar
LS	landing site
MGA	middle gimbal angle
MI	mirror image
MPAD-MSC	Mission Planning and Analysis Division - Manned Spacecraft Center
MSFN	Manned Space Flight Network
OGA	outer gimbal angle
PDI	powered descent initiation
PTC	passive thermal control
RCS	reaction control subsystem
REFSMMAT	reference to stable member coordinate transformation matrix
RR	rendezvous radar
SCT	scanning telescope
SDA	shaft drive axis
SLA	spacecraft LM adapter
SM	service module
SPS	service propulsion system
SXT	sextant
S-IVB	third stage of Saturn V vehicle
TEI	transearth injection
TLI	translunar injection
TPF	terminal phase final
TPI	terminal phase initiation
VHF	very high frequency
ΔV	velocity increment

3. EARTH ORBIT

The S-IVB/SLA/LM/CSM configuration is inserted into a 100-nautical mile altitude circular parking orbit by the Saturn V booster at 00:11:24 g.e.t. The booster/spacecraft attitude at insertion burn termination is inertially fixed for 20 seconds. Following this hold, the S-IVB attitude control system positions the S-IVB (and CSM) X-axis along the local horizontal in the direction of motion. The CSM plus Z-axis is directed along the current position vector. This alignment (which is heads down for the crew) is maintained by an S-IVB orbital pitch rate during the earth orbit phase of the mission. This attitude provides communication coverage during passes over MSFN stations. The local attitude hold is terminated prior to ignition of the TLI burn which occurs at 02:33:27 g.e.t. during the second earth parking orbit revolution. Attitude control for the burn is also through the S-IVB control system.

Spacecraft position and attitude data for the earth orbit phase of the mission are listed in Table II(a). The IMU gimbal angle data for this phase apply to the launch pad alignment of the spacecraft IMU. The transformation matrices (REFSMMAT) for this and other nominal IMU alignments pertaining to various mission phases are given in Table III. Alignment of the IMU to a new inertial reference is noted in both the discussion and the tabular IMU gimbal angle data.



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4. TRANSLUNAR

Presented in this section are major translunar events for which specific attitude sequences have been determined. These events include the transposition, docking, ejection sequence, the spacecraft evasive maneuver, and the PTC periods. Table II(b) lists the spacecraft attitude data for the translunar coast phase which begins at TLI burn termination (02:38:49 g. e. t.) and ends at lunar orbit insertion (LOI-1) burn ignition (75:49:40 g. e. t.). Spacecraft look angles (θ , ϕ) are defined in Figure 1. Preflight attitudes for IMU alignments, midcourse corrections, and cislunar navigation cannot be predicted precisely; attitude data for these events are, therefore, not available. The nominal mission event times are indicated, however, as obtained from Reference 2. Figure 2 is a schematic representation of the major cislunar events.

4.1 Post-TLI Sequence of Events

Termination of the TLI burn occurs at 02:38:49 g. e. t. The S-IVB attitude control system maintains the burnout attitude inertially fixed for 20 seconds following thrust termination. A local horizontal attitude hold is then established by the S-IVB with the CSM plus X-axis forward in the direction of motion and the CSM plus Z-axis up along the local vertical. At TLI cutoff plus 15 minutes, the S-IVB orients the spacecraft/booster configuration to the required inertial attitude for transposition and docking. This attitude, in terms of the local horizontal orientation at TLI cutoff plus 15 minutes, consists of a positive 120-degree pitch, a positive 40-degree yaw, and a roll of 180 degrees for the S-IVB. The CSM orientation is identical except for the roll orientation which is 0 degree for the CSM. With this orientation, the S-IVB and CSM are prepared for the transposition and docking maneuver sequence initiated at TLI cutoff plus 25 minutes with CSM/S-IVB separation. A CSM RCS plus X-axis translation burn of 1 foot per second provides the CSM-S-IVB separation rate. Approximately 2 minutes later, (TLI cutoff plus 27 minutes), the CSM nulls the separation rate and pitches 180 degrees to prepare for the CSM/LM docking maneuver. After aligning to the proper CSM/LM docking index (LM plus Z-axis in the CSM minus Z-plus Y quadrant 60 degrees (± 10 degrees) from the CSM minus Z-axis), the CSM closes with the LM (and S-IVB) and completes the docking maneuver. LM withdrawal is accomplished at approximately TLI plus 90 minutes after which the CSM orients to the S-IVB evasive maneuver attitude. The evasive maneuver burn by the CSM service propulsion system (SPS) is scheduled to occur at TLI cutoff plus 110 minutes. The spacecraft attitude for this maneuver is designed to account for the required SPS thrusting direction, allow the command module pilot (CMP) in the left-hand seat to view the S-IVB through the side window, and also provide CSM high-gain communications. With these considerations, the CSM local horizontal attitude for the burn is pitched 75 degrees below the local horizontal in the direction of motion and rolled positively 60 degrees.

The CSM IMU realignment and cislunar navigation sightings are performed beginning at 05:00:00 g. e. t. The navigation sightings consist of 5 sets of star-earth horizon sightings.

The first midcourse burn is scheduled at 11:33:00 g. e. t. The primary purpose of this burn besides reducing the trajectory dispersions, is to alter the lunar orbit groundtrack to duplicate the G mission groundtrack. This maneuver completes the post-TLI activities. Information for this mission phase was obtained from the F mission flight plan, Reference 2, and References 5 and 6.

4.2 Passive Thermal Control

The translunar coast period following the post-TLI events and ending at the time for the last translunar midcourse correction consists, in terms of spacecraft attitude, primarily of maintaining an acceptable thermal environment for the various spacecraft subsystems. This nominal thermal environment is provided by the PTC mode which involves spinning the spacecraft about the body X-axis at approximately 1 revolution per hour. The spacecraft is aligned initially so that the X-axis is normal (within ± 20 degrees) to the sun, thereby, equalizing the solar heat incidence when the spin is induced. Once the spin rate is established, all RCS control jets may be disabled (true PTC), or the pitch-yaw control may be maintained in wide deadband which is planned for mission F. Two PTC test periods with a 3-revolution per hour spin rate and without attitude control are scheduled for the mission. The first test is conducted with the CSM/LM docked during the translunar coast, and the second test occurs in the transearth coast involving the CSM. The times for these tests are noted in the attitude timeline, Table I. Simulation of PTC periods for this document assumed exact attitude control in all channels (pitch, yaw, and roll). The REFSMMAT used in establishing the spacecraft PTC orientation was defined in accordance with Reference 7. The IMU Y-axis pointing was determined so that the possibility of gimbal lock occurring for transearth midcourse burns is minimized. The PTC attitude is also designed to optimize spacecraft-MSFN communications by orienting the spacecraft X-axis as near normal to the earth line of sight as possible while satisfying the other attitude constraints noted previously.

4.3 S-band High-Gain Antenna Reflectivity Test

At 27:00:00 g. e. t. the spacecraft is oriented to the attitude required to conduct the S-band high-gain antenna (HGA) reflectivity test. The purpose of this test is to provide in-flight data on high-gain signal interference of the docked CSM/LM with the S-band HGA tracking in the CSM plus X-axis direction. The spacecraft attitude at test initiation with respect to the local horizontal orientation is a pitch of minus 80 degrees and a yaw of 20 degrees. Maneuvers subsequent to this initial orientation were not simulated.

4.4 Pre-LOI Events

The pre-LOI sequence of events is assumed to begin at approximately 70:00:00 g.e.t. when the CSM IMU is aligned to the landing site REFSMMAT. This inertial IMU alignment corresponds to a local horizontal attitude of 90.0, 0.0, 0.0 degrees (pitch, yaw, roll) with the nominal (assumed) time of LM touchdown and descent orbit approach azimuth. The IMU realignment is followed at approximately 70:45:00 g.e.t. by a midcourse correction, if required.

At 72:00:00 g.e.t. the spacecraft is maneuvered to an inertial attitude that provides TV coverage of the lunar surface from the center (hatch) window. This orientation consists of a 45-degree pitch and a 180-degree roll maneuver with respect to the lunar local horizontal. In addition to providing the desired TV coverage, the attitude also places the CSM S-band HGA within MSFN line of sight.

The lunar TV coverage is scheduled to end at 72:35:00 g.e.t. Since the spacecraft enters lunar umbra at 72:47:00 g.e.t, a reorientation to the PTC attitude would be impractical, and the inertial attitude used for TV is maintained until approximately 74:45:00 g.e.t. At this time, the spacecraft is oriented to the LOI-1 burn attitude that is maintained inertially fixed until LOI-1 ignition at 75:45:43 g.e.t.



5. LUNAR ORBIT PHASE

This section contains a detailed description of the lunar orbit attitude profile. The events are discussed in chronological order with only those mission events which affect the attitude profile being mentioned.

The mission F lunar orbit profile may be divided into three major segments

1. LOI-1 burn cutoff to CSM/LM undocking
2. CSM/LM undocking to LM jettison
3. LM jettison to TEI burn ignition

The discussion will be divided into these segments with the first and third segments being discussed primarily revolution by revolution, while the second segment is discussed according to major events. For the purpose of this document, a vehicle revolution will be referenced to the lunar surface. The first vehicle revolution is assumed to start at LOI-1 burn cutoff and end at 180 degrees selenographic longitude. All other revolutions start and end at 180 degrees selenographic longitude except the thirty-second revolution which ends at TEI burn ignition.

Detailed trajectory and attitude data for the lunar orbit phase of the mission is presented in Table II(c). Part 1 of Table II(c) presents LOI-1 burn cutoff to CSM/LM undocking. Part 2 of Table II(c) presents all of the two-vehicle data for the lunar orbit phase from CSM/LM undocking to the LM unmanned APS burn to depletion cutoff. Part 3 of Table II(c) presents the portion of the lunar orbit phase from the LM unmanned APS burn to depletion cutoff to TEI burn ignition. It should be noted that the IMU gimbal angle data presented in Table II(c) are based on the landing site REFSMMAT. The CSM and LM IMU's are aligned to the landing site REFSMMAT throughout the lunar orbit phase of the mission.

5.1 LOI-1 Burn Cutoff to CSM/LM Undocking

5.1.1 First revolution (Figure 3). - The LOI-1 burn is designed to deboost the CSM/LM from the cislunar trajectory and place it into a 60-by 170-nautical elliptical lunar parking orbit. The burn is performed with the CSM SPS engine. The CSM is in a retrograde attitude, and the crew is heads down to afford visual reference with the lunar surface. The LOI-1 burn cutoff attitude is maintained following the burn until approximately 12 minutes prior to acquisition of MSFN line of sight. The CSM is then rolled 180 degrees (right) to provide CSM S-band HGA communications. This attitude is maintained inertially fixed until communications with MSFN have been established. The vehicle is then maneuvered to a lunar observation attitude. The CSM attitude, with respect to the local horizontal orientation, is a pitch of -45 degrees and a roll of 180 degrees.

This lunar observation attitude allows observation of the CSM/LM ground-track through the CSM hatch window and oblique views of the lunar surface through each of the CSM side windows. This lunar observation attitude is held locally fixed until the vehicle enters darkness. At this time the local attitude hold is terminated, and the existing vehicle attitude is maintained inertially fixed to allow a CSM IMU realignment. The IMU realignment occurs approximately 5 minutes after the vehicle enters darkness and is a realignment to the lunar landing site REFSMMAT. Approximately 17 minutes prior to the loss of MSFN line of sight, the CSM/LM is maneuvered to the lunar orbit sleep attitude for an evaluation of the CSM HGA communications mode to be used during lunar orbit sleep. The lunar orbit sleep attitude will be more fully discussed in one of the following sections, but the attitude is an inertial attitude such that the CSM local horizontal angles at the subsolar point would be a pitch of -140 and a roll of 135 degrees. To fully evaluate the communications mode, the CSM/LM must remain in an inertially fixed attitude from loss of MSFN line of sight to acquisition of MSFN line of sight. Thus, the vehicle attitude is maintained inertially fixed through the completion of the first revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.1.2 Second revolution (Figure 4). - At the completion of the first vehicle revolution, the spacecraft is in the inertially fixed lunar orbit sleep attitude for an evaluation of the lunar orbit sleep communications reacquisition mode. This attitude is held inertially fixed until completion of the communications test. Approximately 10 minutes after acquisition of MSFN line of sight, the CSM is rolled 45 degrees (right) to improve lunar observation near the lunar morning terminator. The resulting attitude is maintained inertially fixed until the time to maneuver to the LOI-2 burn attitude. The inertial attitude satisfies the attitude requirements for an IMU realignment to the landing site REFSMMAT that occurs immediately after the CSM/LM enters darkness. Approximately 25 minutes before loss of MSFN line of sight, the CSM/LM is maneuvered to the LOI-2 burn attitude. This attitude is maintained through the completion of the second revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight until the maneuver to the LOI-2 burn attitude.

5.1.3 Third revolution (Figure 5). - Following the start of the third revolution, the LOI-2 burn is performed. This burn is the circularization burn that transforms the initial elliptical parking orbit into a 60-nautical mile circular lunar orbit. The burn is performed with the CSM SPS engine with the CSM in a retrograde attitude. The CSM roll attitude allows the crew to be heads down during the burn to allow visual reference with the lunar surface. Following burn cutoff the LOI-2 burn attitude is maintained. Approximately 10 minutes prior to acquisition of MSFN line of sight, the CSM is rolled 180 degrees (right) to provide CSM S-band HGA communications. The resulting attitude is maintained inertially fixed until communications with MSFN have been established. The vehicle is then maneuvered to the lunar observation attitude. The same attitude which

was used in the first revolution is utilized. The CSM attitude, with respect to the local horizontal orientation is a pitch of -45 degrees and a roll of 180 degrees. This attitude allows observation of the vehicle groundtrack through the CSM hatch window and oblique views of the lunar surface through each of the CSM side windows. This attitude is held locally fixed until just prior to the vehicle entering into darkness. This attitude should allow through-the-window observation of the landmarks to be tracked during the next vehicle revolution. In addition, a possible 10-minute TV transmission is scheduled at mission time 80:45:00. This attitude will provide S-band HGA communications and will allow a view of the lunar surface. Prior to the vehicle entering darkness, the local attitude hold is terminated, and the existing vehicle attitude is held inertially fixed until the CSM/LM enters into sunlight. This inertial attitude will allow a CSM IMU realignment to the landing site REFSMMAT that occurs approximately 7 minutes after the CSM/LM enters darkness. As the vehicle enters into sunlight, the CSM/LM is maneuvered to the initial landmark tracking attitude for the landmark tracking on F-1 (a lunar landmark to be tracked in the fourth vehicle revolution). The initial landmark tracking attitude is a pitch 2.1 degrees below the local horizontal orientation 90 seconds before the CPA to F-1 (approximately 35 degrees elevation). This initial landmark tracking attitude is maintained through the completion of the third vehicle revolution. It should be noted that approximately 3 minutes after the loss of MSFN line of sight the LM is occupied, and LM attitude requirements must be taken into account. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.1.4 Docked lunar landmark tracking. - A complete list of the lunar landmarks which will be tracked during the lunar orbit phase is presented in Table IV. This list was obtained from Reference 8. An IP is a prominent initial point which aids the astronaut by leading him into the landmark to be tracked. The geometry for lunar landmark tracking is defined by Figures 6 and 7. The acceptable marking region is defined as the area from 35 degrees elevation to 35 degrees elevation. The period of time the spacecraft remains in the acceptable marking region is on the order of 3 minutes. Marks taken within this region must be equally spaced and at least 25 seconds apart. Five marks are required on each landmark, with a minimum time of 100 seconds required between the first and the last mark. The primary consideration is that the marks be taken over a wide spread of elevation geometry. The SCT will be used to acquire the landmark, and the SXT will be used to track the landmark.

The landmark tracking attitude mode to be used for docked lunar landmark tracking is a mode I type. A complete discussion of the lunar landmark tracking attitude modes available for landmark tracking is presented in Reference 9. Mode I tracking consists of an inertial attitude hold with the CSM X-Z plane approximately in the lunar orbit plane. As the spacecraft approaches the landmark, a pitch rate is added to allow the landmark to remain in the optical fields of coverage while the spacecraft

is in the acceptable marking region. The geometry for the particular mode I tracking used is presented in Figure 8. The initial inertial attitude is such that the CSM is pitched 2.1 degrees below the local horizontal orientation at 90 seconds before the CPA. A -0.3 degree per second pitch rate is added at 35 degrees elevation and is maintained until the vehicle exits the acceptable marking region approximately 90 seconds after the CPA. At the termination of the pitch rate the CSM X-axis lies approximately 47 degrees below the local horizontal. The landmark enters the SCT field of coverage 148 seconds before the CPA (21 degrees elevation) and enters the SXT field of coverage 112 seconds before the CPA (28.2 degrees elevation). The landmark is still in both the SXT and SCT fields of coverage at the termination of the pitch rate.

To aid the astronaut in landmark tracking, two times, T_1 and T_2 , will be updated to the astronaut in real time. T_1 is the g. e. t. when the spacecraft comes across the landmark topocentric horizon. This is primarily an astronaut alert time. T_1 occurs approximately 390 seconds before the CPA to the landmark. T_2 is the g. e. t. to start the pitch rate. T_2 occurs approximately 90 seconds before the CPA.

As a result of the maximum rate limits of the optics shaft and trunnion angles, there are certain zones in the optical coverage area where the optics line of sight cannot keep up with the coverage of the landmark. This occurs when the groundtrack of the optics shaft axis passes close to the landmark. In mission F, the optical blind zone will be avoided by rolling the spacecraft so that the minimum trunnion angle is at least 10 degrees. This maneuver will be added in real time, and is not simulated here. The required roll is small, and the times given above are not appreciably affected. The optics shaft and trunnion angles given in Table II(c) are the optics angles required to center the optics line of sight along the vehicle to landmark line of sight at 35 degrees elevation before the CPA. These angles do not reflect the roll maneuver required to avoid the optics blind zone. Detailed shaft and trunnion plots are available for each landmark but will not be presented in this document.

5.1.5 Fourth revolution (Figure 9). - At the beginning of the fourth revolution the spacecraft is in the initial inertial attitude for landmark tracking on F-1. A mode I type tracking sequence is performed on F-1, and at the conclusion of the tracking sequence the vehicle pitch rate is terminated and the spacecraft is maneuvered to the initial inertial attitude for landmark tracking on B1. Because of the pitch rate for the mode I tracking, only a small pitch maneuver is required. A mode I type tracking sequence is performed on B1, and at the completion of the sighting sequence the spacecraft pitch rate is terminated and the spacecraft is maneuvered to the lunar orbit sleep attitude. CSM S-band HGA communications will not be available during the landmark tracking sequences. The lunar orbit sleep attitude is the same used for the communication test in the first revolution. The CSM inertial attitude is such that the CSM is pitched -140 degrees and rolled 135 degrees from the local horizontal orientation at the subsolar point. Approximately 3 minutes after the spacecraft enters darkness, 25 minutes of LM communications tests start.

Before the start of these tests, the CSM RCS thrusters that might cause impingement on the LM S-band steerable antenna when unstowed are disabled. These thrusters are RCS jets B-3 and C-4. With these thrusters disabled, the LM steerable antenna may track outside of the preseparation pointing region. The lunar orbit sleep attitude will allow both CSM and LM S-band steerable communications with MSFN. This sleep attitude is held inertially fixed through the completion of the fourth revolution. Another test of the lunar orbit sleep reacquisition mode is provided before the crew starts its sleep period. The LM is vacated approximately 15 minutes after loss of MSFN line of sight.

5.1.6 Fifth revolution (Figure 10). - At the start of the fifth revolution, the spacecraft is in the inertially fixed lunar orbit sleep attitude. At acquisition of MSFN line of sight a test of the lunar orbit sleep communications reacquisition mode is provided. An 8-hour lunar sleep period is started approximately 20 minutes after the acquisition of MSFN line of sight. The lunar orbit sleep attitude is maintained inertially fixed through the completion of the fifth revolution. CSM S-band HGA communications are available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.1.7 First lunar orbit sleep period (Figures 11, 12, 13, and 14). - The inertial lunar orbit sleep geometry is shown in Figure 15. An inertial attitude hold is used to minimize RCS fuel usage and to provide continuous CSM S-band HGA communications when line of sight to earth exists. The attitude must be compatible with CSM S-band HGA communications. Also, RCS quad cold problems must be avoided. The thermal constraints may be avoided by placing the CSM X-axis normal to the sun plus or minus some bias. The allowable bias is approximately 40 degrees. The CSM must also be rolled so that direct sunlight "splits" two RCS quads. This insures that all the quads receive some heating. Two quads receive direct sunlight, and the other two quads receive reflected heat from the lunar surface. A flight crew constraint is that the CSM X-axis remain in-plane during the sleep period. All these constraints are satisfied by the inertial lunar orbit sleep attitude. The 40-degree bias and the roll to split the RCS quads is taken in such a way that communications are improved. The inertial attitude is such that the CSM is pitched -140 degrees and rolled 135 degrees from the local horizontal orientation at the subsolar point. The longitude of the subsolar point used in calculating the attitude is the longitude at the nominal time of starting the crew sleep period. The attitude is kept in a G&N attitude hold with a ± 10 -degree dead band throughout the lunar orbit sleep period. Two adjacent RCS quads are used for attitude control. Additional information on the lunar orbit sleep attitude may be obtained from Reference 10. The lunar orbit sleep period lasts approximately 8 hours, being terminated late in the ninth revolution. The inertial sleep attitude is maintained through the completion of the ninth revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight in each vehicle revolution.

5.1.8 Tenth revolution (Figure 16). - At the beginning of the tenth revolution, the spacecraft is in the inertial lunar orbit sleep attitude and the crew is awake. This attitude is maintained inertially fixed until approximately 4 minutes prior to loss of MSFN line of sight. The LM is occupied approximately 8 minutes after acquisition of MSFN line of sight, and the sleep attitude provides LM steerable antenna communications for the LM communications checks. The sleep attitude also satisfies the attitude requirements for a CSM IMU realignment to the landing site REFSMMAT, which occurs approximately 2 minutes after the CSM/LM enters into darkness. Prior to loss of MSFN line of sight the spacecraft is maneuvered to the initial inertial attitude for a mode I landmark tracking to be performed on landmark 130 in the eleventh revolution. This attitude is held inertially fixed through the completion of the tenth revolution. CSM and LM S-band steerable communications will be available from acquisition of MSFN line of sight until the maneuver to the landmark tracking attitude.

5.1.9 Eleventh revolution (Figure 17). - At the beginning of the eleventh revolution the spacecraft is in the initial inertial attitude for a mode I landmark tracking on landmark 130. This attitude is held inertially fixed until 90 seconds before the CPA to landmark 130. After the completion of the mode I landmark tracking sequence on landmark 130, the spacecraft is maneuvered to an attitude that is rolled 180 degrees from the CSM/LM undocking attitude. CSM and LM S-band steerable communications were not available during the landmark tracking sequence, but this maneuver allows CSM and LM S-band steerable communications. This attitude is held inertially fixed until approximately 3 minutes after loss of MSFN line of sight. The spacecraft is then rolled 180 degrees (right) to the undocking attitude and held inertially fixed while LM checkout continues.

Approximately 25 minutes before undocking, the vehicle is yawed 14 degrees (right) for a LM AGS calibration. After completion of the AGS calibration, the spacecraft is yawed -14 degrees (left) to return to the undocking attitude. The undocking attitude is then held inertially fixed until CSM/LM undocking. This occurs early in the twelfth revolution. CSM and LM S-band steerable antenna communications are available from the completion of landmark tracking until loss of MSFN line of sight.

5.2 Undocking to LM Jettison

5.2.1 Undocking to DOI (Figure 18). - Undocking will occur at 98:10:00 g. e. t., which is approximately 25 minutes prior to the CSM-RCS separation burn. The orientation of the vehicles is such that the LM is ahead of the CSM. The CSM is in-plane, heads down and pitched 13.3 degrees above the local horizontal. This attitude is the CSM inertial separation burn attitude except for a 180-degree roll angle that shades the CSM windows during the LM inspection. Following undocking the LM will null the relative range rate after a separation distance of 40 to 50 feet is achieved. The CSM will then station keep at this distance while the LM performs a 120-degree negative roll (pilot yaw right) maneuver and a

90-degree positive pitch maneuver. This will place the LM heads down and at an attitude where the crews will be eye to eye. The CMP will then inspect and photograph the LM landing gear and descent engine bell while the LM does a rotation maneuver (pilot yaw right) of 2 degrees per second for 360 degrees. Immediately after completion of the inspection, the LM will begin station keeping and the CSM will manually roll 180 degrees to acquire the MSFN with the HGA. These attitudes are held inertially fixed until after the CSM-RCS separation burn cutoff.

Separation is accomplished by the CSM X-axis RCS thrusters applying a ΔV of 2.5 feet per second radially downward. This maneuver is performed at approximately 180 degrees central angle prior to DOI. At separation burn ignition the CSM is in-plane and pitched 90 degrees above the local horizontal (positive X-axis is coincident with the radius vector). An attitude maneuver should not be required at this time since the CSM undocking attitude was the inertial separation burn attitude. The LM will have performed small translation maneuvers during the LM station keeping phase so that it will be above and slightly ahead of the CSM at separation. This will allow the LM to visually monitor the CSM-RCS separation burn while maintaining an attitude that is favorable for establishing the RR tracking attitude which follows separation. Each spacecraft will be in an attitude favorable for HGA communications during the separation burn.

Following the CSM separation burn, the CSM and LM will be maneuvered (pitched) automatically to the required attitudes for CSM SXT tracking - VHF ranging and LM RR tracking. The necessary tracking attitude results in the center of the common coverage of the CSM SXT and RR transponder to be pointing at the LM (35 degrees from the positive X-axis toward the positive Z-axis measured in the X-Z plane). Likewise, the center of coverage of the LM tracking light should be pointing at the CSM (along the positive Z-axis). This attitude is also the preferred attitude for LM RR coverage. For this tracking period, and for all subsequent CSM/LM tracking, the CSM is oriented in a heads down attitude and the LM in a heads up attitude. The initial attitudes of the vehicles allow for CSM SXT/RR transponder and LM RR/tracking light line-of-sight maintenance. The amount each vehicle is pitched in order to obtain the preferred track axis (vehicle-to-vehicle look angles discussed above) is dependent upon the relative positions of the vehicles at the time of separation. Assuming that the LM is 50 feet above and 5 feet ahead of the CSM at separation, the CSM will be pitched approximately 35 degrees and the LM will be pitched approximately 0.5 degree following the CSM separation burn cutoff in order to obtain the preferred track axis.

The CSM and LM will perform an IMU realignment beginning about 5 minutes after sunset. Both vehicles will be in inertial attitude hold during the IMU realignments and will continue in this mode until 6 minutes prior to LM DOI burn ignition. At this time the CSM will begin an automatic maneuver to the preferred track axis discussed previously in order to monitor the LM burn and to provide radar transponder coverage. The LM will begin an automatic maneuver to the inertial DOI burn attitude which is a retrograde, in-plane orientation. The LM DPS DOI burn ignition occurs at 99:33:59 g. e. t.

The attitude of the CSM from the time it performs a 180-degree roll maneuver subsequent to the LM inspection to LOS is favorable for HGA communications. The attitude of the LM from the time the LM begins station keeping until LOS is favorable for HGA communications.

A relative motion plot of the two spacecraft from separation to DOI is illustrated in Figure 19. It was assumed that the LM was approximately 50 feet above the CSM at separation. The attitude sequences from undocking to DOI were developed by utilizing the crew procedures information presented in References 11 and 12.

5.2.2 DOI burn cutoff to phasing burn ignition (Figure 20). - The CSM-LM relative motion for the lunar orbit phase from DOI to docking is shown in Figure 21.

Following cutoff of the DPS DOI burn at 99:34:27 g.e.t., the LM orients to the RR tracking attitude described in the preceding section. This tracking interval lasts for approximately 15 minutes after which the LM orients to the inertial powered descent initiation (PDI) attitude. The PDI attitude is defined at pericynthion of the descent orbit by a LM retrograde, local horizontal, and face down orientation. The CSM continues to track the LM for an onboard determination of the LM descent orbit state vector. Following DOI cutoff, the CSM continues SXT tracking - VHF ranging operations until termination of the LM phasing burn (assuming both of these burns are nominal). Reference 11 contains the CSM contingency procedures for the CSM-LM rendezvous. This CSM tracking period is interrupted shortly before MSFN line-of-sight acquisition for the CSM to perform a 180-degree roll maneuver. This maneuver places the CSM plus Z-axis forward, in the direction of motion, providing S-band HGA communications at MSFN acquisition. Following the roll maneuver, the CSM is reoriented to the tracking attitude, and SXT tracking - VHF ranging is resumed. The CSM tracking profile from MSFN acquisition to nominal phasing burn cutoff permits MSFN coverage through the HGA. CSM and LM tracking periods were obtained from Reference 13 with two exceptions. First, the prephasing tracking for the CSM was obtained from Reference 11 and the post-DOI LM tracking was agreed upon in an F mission data priority meeting on March 10, 1969. The second exception is the inclusion of a LM-IMU realignment lasting 15 minutes during the post-phasing tracking period. The termination of this tracking period for the LM was also changed to 5 minutes prior to LM loss of MSFN line of sight. This change was obtained informally from the Math-Physics Branch - MSC. It is emphasized that CSM and LM preinsertion tracking periods are subject to change and the times shown in this report for these periods should not be regarded as final.

The LM acquires earth line of sight in the PDI attitude. A negative roll (pilot yaw right) of 180 degrees and a negative pitch maneuver is executed in preparation for the landing radar (LR) test. The direction of the roll (pilot yaw) is required to verify the ability to maintain S-band high-gain communications during this maneuver, and the pitch maneuver orients the LM to the local vertical (LM plus X-axis up). A pitch rate of approximately -0.055 degree per second is induced with the LM X-axis pitched back 10 degrees from the local vertical. The LR test is initiated

400 seconds prior to pericyynthion of the descent orbit trajectory and ends 600 seconds later. The landing site is visible through the LM window for approximately 1 minute during the test. The spacecraft attitude sequence for the LR test is shown in Figure 22. Note from the figure that the LM could be reoriented, following LR test completion, to increase the landing site observation time.

Upon completion of the LR test, the LM prepares for the DPS phasing burn. The inertial burn attitude (plus X-axis 29 degrees above the local horizontal in the direction of motion and face down at ignition) is established 8 minutes prior to ignition which occurs at 100:46:21 g. e. t. The LM attitude profile from MSFN acquisition to ignition provides HGA-MSFN line of sight.

5. 2. 3 Phasing burn cutoff to insertion burn ignition (Figure 23). - The DPS phasing burn cutoff is at 100:47:03 g. e. t. with the LM holding the burn attitude inertially until executing a pitch and roll (pilot yaw) maneuver for RR tracking of the CSM starting 5 minutes after burn termination. The CSM, upon confirming the burn is nominal, continues the line-of-sight maintenance tracking attitude rate and resumes tracking beginning 5 minutes after the burn. The LM tracking attitude at the end of the 10-minute tracking period is held inertially fixed for the LM IMU realignment mentioned previously. The CSM also tracks for 10 minutes and maintains the final tracking attitude inertially fixed.

The CSM and LM initiate tracking again at 101:17:03 g. e. t. At 101:20:47 g. e. t. (5 minutes prior to loss of MSFN line of sight by the LM) the LM terminates tracking. The LM orientation at the end of tracking is maintained inertially until resumption of LM RR tracking at 101:59:18 g. e. t. The CSM terminates tracking at 101:27:03 g. e. t. holding the final tracking attitude inertially fixed until the next tracking period beginning at 101:48:18 g. e. t. LM and CSM attitudes for the period from phasing burn cutoff to loss of MSFN provide HGA communication for both vehicles.

After the CSM ceases tracking at 102:18:18 g. e. t., the vehicle maneuvers to the inertial mirror image (MI) insertion burn attitude. The MI burn attitude is a means of providing CSM backup capability for the LM rendezvous burns from insertion to the final braking maneuvers (the CSM nominally performs the docking maneuver). The MI burn attitude consists of aligning the CSM propulsion system (SPS or RCS) in a thrusting direction opposite the LM burn orientation. Ignition for the MI burn is scheduled at 3 minutes after the nominal time of ignition for the LM burn.

The CSM MI insertion burn attitude, at the time of LM insertion burn ignition, has the plus X-axis 26.8 degrees above the local horizontal in the direction of motion with the crew heads down. The MI burn attitude is maintained until the LM burn is performed and verified. The CSM acquires MSFN in the MI burn attitude with the S-band HGA oriented nominally for MSFN coverage.

The LM terminates tracking at 102:19:18 g. e. t. and prepares for jettison of the descent stage. The jettison maneuver sequence begins at 102:33:18 g. e. t. with the LM orienting to a retrograde, face down local horizontal attitude. An RCS minus X-axis burn of 2 feet per second is then executed. Shortly after this burn, the LM RCS plus X-axis thrusters are fired to provide a 2-foot per second retrograde ΔV increment. During this burn, the descent stage is jettisoned. The object of these maneuvers is to place the descent stage in a higher orbit and return the LM ascent stage to essentially the original (phasing) orbit. This results in the descent stage being behind and above the LM ascent stage at insertion burn ignition, thereby, minimizing the probability of recontact between the ascent stage and descent stage during the burn.

Following descent stage jettison, the LM prepares for the ascent propulsion subsystem (APS) insertion burn. The LM insertion burn attitude at ignition (102:43:18 g. e. t.) is with the LM plus X-axis 24. 4 degrees above the local horizontal opposite the direction of motion and the plus Z-axis towards the moon. The LM attitude from MSFN acquisition to burn ignition provides high-gain coverage with the MSFN.

5. 2. 4 Insertion burn cutoff to CDH burn ignition (Figure 24). - Burn termination for the APS insertion burn occurs at 102:43:33 g. e. t. The LM holds the burnout attitude inertially until time to orient for a RR tracking period beginning 18 minutes after burn cutoff. The reorientation maneuver to the initial tracking attitude involves a 180-degree roll (pilot yaw) and pitch of 120 degrees to point the plus Z-axis approximately along the local horizontal in the direction of motion.

The CSM, upon confirmation of a nominal APS insertion burn, orients from the MI insertion burn attitude to a retrograde, heads down inertial attitude. The purpose of this orientation is to establish a suitable attitude for performing an IMU realignment and provide S-band HGA-MSFN line of sight. This attitude also prepares the CSM for the SXT tracking - VHF ranging period starting 23 minutes after insertion burn termination.

The CSM and LM track until approximately 16 minutes and 11 minutes, respectively, prior to the CSI burn. At these times the vehicles maneuver to their inertial CSI burn attitudes (LM posigrade local horizontal and face down, CSM retrograde local horizontal and heads up at RCS burn ignition). Both CSM and LM high-gain communications are satisfactory throughout the time from insertion burn cutoff to loss of MSFN.

The LM performs the CSI burn with the plus X-axis RCS thrusters beginning at 103:33:46 g. e. t. The burn attitude is maintained inertially and the LM prepares for another period of RR tracking starting 6 minutes after the CSI burn. This maneuver consists of pitching the Z-axis up to the local horizontal in the direction of motion.

The CSM, after verifying the LM CSI burn was nominal, also orients to the SXT tracking - VHF ranging attitude. The maneuver is essentially a roll of 180 degrees to establish the initial heads-down tracking attitude.

The roll maneuver is required because the MI CSI burn attitude is heads up to allow MSFN coverage until loss of signal. The CSM tracking period also starts 6 minutes after the burn.

After this period of tracking (20 minutes for the CSM and 17 minutes for the LM), another tracking interval is started 9 minutes later for the LM and 5 minutes later for the CSM. The LM plane change maneuver occurs in this break but is not simulated in this document. After resuming tracking, both vehicles maintain the respective tracking attitude for the duration of the period which ends at 104:20:18 g. e. t. In this second period, MSFN line of sight is acquired. The LM tracking attitude provides S-band high-gain lock but the CSM attitude violates high-gain antenna pointing constraints. High-gain communications requirements are satisfied, however, when the CSM orients to the inertial MI CDH burn attitude (retrograde local horizontal and heads down at LM RCS ignition). The LM inertial CDH burn attitude (plus Z-axis forward along the local horizontal and heads up at ignition) also provides MSFN coverage with the LM steerable antenna. The LM orients to the CDH burn attitude following the RR tracking ending at 104:20:18 g. e. t. CDH burn ignition is at 104:31:42 g. e. t. The four RCS minus X-axis thrusters perform the burn with the thrust direction radially downward.

5.2.5 CDH burn cutoff to docking (Figure 25). - After cutoff of the CDH burn at 104:31:45 g. e. t., the LM and CSM begin another period of tracking 4 and 5 minutes later, respectively. The CSM and LM tracking attitudes provide high-gain coverage during this period. Both vehicles hold the tracking attitude inertially at the end of the period (17 minutes and 19 minutes in length for the CSM and LM, respectively) until executing their TPI burn attitude orientation. The LM performs TPI with the plus X-axis jets in a heads up posigrade attitude. The CSM MI burn attitude is heads down and retrograde at the nominal time of ignition (105:08:57 g. e. t.). Following TPI cutoff at 105:09:13 g. e. t., two short periods of tracking by the CSM and LM occur prior to the LM RCS braking burn at 105:50:14 g. e. t. (The CSM-LM separation at burn ignition is 3000 feet. The first braking burn at a separation distance of 5000 feet was not required in the rendezvous maneuver simulation. All braking burns are performed by the RCS minus Z-axis thrusters.) The first of the two tracking periods is within sight of MSFN stations. The CSM and LM HGA positions are acceptable for MSFN acquisition until loss of signal.

The CSM maintains the required line-of-sight tracking attitude during the subsequent LM braking maneuvers. The LM also continues with the nominal RR tracking attitude (plus Z-axis pointed at the CSM) between the braking burns. This tracking profile is compatible with the line-of-sight thrust direction (along the LM minus Z-axis).

The final LM braking burn (at 100 feet CSM-LM separation distance) is performed at 105:56:36 g. e. t. The CSM-LM range at burn termination is approximately 85 feet with an approximate closing rate of 0.2 foot per second. When the LM closes to within 50 feet of the CSM (the LM is ahead and slightly below the CSM at this point), both vehicles begin final docking preparations. The LM pitches negatively through 90 degrees to point the LM plus X-axis at the CSM. The vehicle-to-vehicle line of sight is then

approximately normal to the sun line of sight. As noted earlier, the CSM executes the closing translational maneuvers required for docking. Completion of the CSM/LM docking maneuver was assumed at 106:20:00 g. e. t.

5.2.6 Docking to LM jettison (Figure 26). - After post-docking checks, the spacecraft is maneuvered to the LM jettison attitude. The attitude is such that the LM is in the correct inertial burn attitude for the APS burn to depletion, which occurs approximately one revolution after docking. The attitude must also provide LM HGA communications for MSFN tracking of the burn. This attitude is held inertially fixed until time for LM jettison at 108:29:24 g. e. t.

5.3 LM Jettison to TEI Burn Ignition

5.3.1 LM jettison to end of seventeenth revolution (Figure 27). - Since the LM APS burn to depletion is an unmanned burn, the LM must be jettisoned in the correct inertial attitude for the APS burn. The LM jettison attitude is such that the LM is in the local horizontal orientation at the LM APS burn ignition (108:38:57 g. e. t.). The LM jettison occurs at 90 degrees east selenographic longitude with the CSM pitched 90 degrees and rolled -60 degrees from the local horizontal orientation. Immediately following jettison, the CSM is translated above the LM, using short RCS thrusts. After translating above the LM, a CSM ΔV of 2 feet per second is applied radially upward to effect final separation. This evasive maneuver puts the CSM above and behind the LM at the APS burn ignition. Following the evasive maneuver, the CSM is maneuvered to a LM observation attitude. This attitude is an inertially fixed attitude that allows the LM APS burn to be seen through the CSM hatch and rendezvous windows. This attitude also allows CSM S-band HGA communications.

The unmanned LM APS burn to fuel depletion is initiated with the LM at 0 degree selenographic longitude. The burn is an in-plane, posigrade, face-down burn with the LM aligned along the local horizontal orientation at burn ignition. The burn is targeted to place the LM ascent stage in solar orbit. The LM remains in continuous line of sight with MSFN with LM S-band steerable antenna coverage available for monitoring of the LM for several hours after the burn.

Following the LM burn and approximately 16 minutes before loss of MSFN line of sight, the CSM maneuvers to the lunar orbit sleep attitude. This attitude is held inertially fixed through the completion of the seventeenth revolution. Both CSM and LM S-band steerable antenna communications are available during the seventeenth CSM revolution whenever line of sight to MSFN exists.

5.3.2 Second lunar orbit sleep period (Figures 28, 29, 30, and 31). - The CSM attitude during the second lunar orbit sleep period will be the same attitude as that for the first lunar orbit sleep period. This sleep period, following the strenuous rendezvous day, will be approximately 9 hours long with sleep terminating early in the twenty-second revolution.

The inertial attitude hold during the sleep period will provide CSM S-band HGA communications from acquisition of MSFN line of sight to loss of MSFN line of sight during each revolution.

5.3.3 Twenty-second revolution (Figure 32). - Early in the twenty-second revolution, the second lunar orbit sleep period is terminated. Approximately 5 minutes after acquisition of MSFN line of sight, the CSM is maneuvered to the initial attitude for an oblique photography sequence of LS2. A schematic of an oblique photography sequence is shown in Figure 33. The camera used for the photography sequence will be placed in a bracket that is mounted in the CSM right-hand rendezvous window. The camera optical axis, using the bracket, will be pitched 12 degrees (up) from the CSM X-axis (Reference 14). The oblique photography attitude sequence will allow the LS line of sight to remain within a 15-degree half-angle cone about the camera optical axis. The initial attitude for the photography sequence will allow the LS to be seen as the spacecraft crosses the LS topocentric horizon. The CSM is pitched -8 degrees and rolled 180 degrees from the local horizontal orientation. This attitude is held locally fixed until approximately 20 degrees elevation from LS2. A 0.5 degree per second pitch rate is then initiated to keep LS2 in the camera field of view. The pitch rate is terminated at the LS zenith. The spacecraft attitude is changing faster than the LS line of sight during the period the spacecraft is at low elevation angles. The maximum backup occurs at approximately 47 degrees elevation, after which the LS line of sight changes faster than the spacecraft attitude. At the completion of the sequence the spacecraft has been pitched approximately 78 degrees below the local horizontal.

At the completion of the oblique photography sequence, the pitch rate is terminated and the existing attitude is held inertially fixed. This attitude satisfies the requirements for an IMU realignment to the landing site REFSMMAT, which occurs approximately 7 minutes prior to loss of MSFN line of sight. Prior to the CSM entering into sunlight, the spacecraft is maneuvered to an attitude that allows vertical strip photography of the spacecraft groundtrack. The spacecraft attitude is a pitch of -78 degrees and a roll of 180 degrees from the local horizontal orientation. This allows the camera optical axis to be pointed vertically down and allows the spacecraft windows to be shaded from the sun. This attitude is held locally fixed through the completion of the twenty-second revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.3.4 Twenty-third revolution (Figure 34). - At the beginning of the twenty-third revolution, the CSM is in the locally fixed strip photography attitude. This attitude is maintained locally fixed until the spacecraft reaches the subsolar point. The CSM is then maneuvered to shade the spacecraft windows from the sun. The CSM attitude, with respect to the local horizontal orientation, is then a pitch of -102 degrees. This attitude allows the camera optical axis again to be pointed vertically down. This attitude is maintained locally fixed. As the spacecraft approaches LS1, the CSM is yawed 20 degrees (right) to include LS1 in the photography.

After passing LS1, the CSM is yawed -20 degrees (left) to place the camera axis back on the spacecraft groundtrack. The strip photography attitude is maintained locally fixed until the lunar morning terminator is reached. At the terminator, the spacecraft is maneuvered to an IMU realignment attitude. This inertial attitude satisfies the attitude requirements for the IMU realignment to the landing site REFSMMAT, which occurs approximately 2 minutes after the spacecraft enters darkness. The IMU realignment attitude also sets up the undocked landmark sighting attitude for the series of sightings starting early in the twenty-fourth revolution. The IMU realignment attitude is held inertially fixed until the CSM becomes pitched 22 degrees below the local horizontal orientation. The inertial attitude hold is then terminated, and a local attitude hold is initiated for the landmark sightings. This attitude is maintained locally fixed through the completion of the twenty-third revolution. CSM S-band HGA communications will be available from the maneuver to the IMU realignment attitude until loss of MSFN line of sight.

5.3.5 Undocked lunar landmark tracking. - During the undocked landmark tracking periods, several lunar landmarks are to be tracked in each vehicle revolution. Because of this, a relatively simple spacecraft attitude mode which does not require attitude reorientations between sightings should be used. In addition, LM blockage, which obscured part of the CSM optics during docked sightings, is no longer a problem for the undocked sightings. For these reasons, mode III type landmark tracking will be used for the undocked landmark sightings (Reference 9). The spacecraft attitude, with respect to the local horizontal orientation, during undocked sightings is a pitch of -22 degrees. The geometry of the mode III type landmark tracking is shown in Figure 35. The landmark enters the SCT field of coverage 100 seconds before the CPA (32 degrees elevation) and exits the SXT field of coverage 56 seconds past the CPA (49.7 degrees elevation). Although the tracking and acquisition times are significantly reduced over those of the mode I docked sightings, the landmark remains in the SXT field of coverage for 146 seconds within the acceptable mark region. This should be adequate time to obtain the required 5 marks. It should be pointed out, if trouble occurs in obtaining the marks, additional tracking time can be made available by adding a small pitch rate near the end of the tracking period. The optical blind zone constraint may be satisfied, as in the docked sightings, by rolling the spacecraft as the landmark is approached to assure a minimum trunnion angle of at least 10 degrees.

Two times, T_1 and T_2 , are used during undocked landmark sightings to help in acquiring the correct landmark. T_1 occurs when the spacecraft is 35 degrees elevation from the IP for the landmark. T_2 occurs when the spacecraft is 35 degrees elevation from the landmark. The times listed in Table II(c) for the beginning of tracking of the landmarks are the T_2 times.

5.3.6 Landmark tracking revolutions (Figures 36, 37, 38, and 39). - Revolutions twenty-four, twenty-five, twenty-six, and twenty-seven are very similar. A series of four landmarks are tracked on each of these

four consecutive revolutions. The landmarks to be tracked on these revolutions are CP₁, CP₂, F-1, and landmark 130. Of these, it is not mandatory to track F-1, but it is included in the timeline to be tracked if sufficient time is available without endangering the tracking of the other three landmarks.

During each vehicle revolution, the mode III local horizontal attitude is maintained throughout the tracking of the four landmarks. On revolutions 24, 25, and 26, after the completion of landmark tracking on landmark 130, the CSM is maneuvered to an IMU realignment attitude. This attitude satisfies the requirements for the IMU realignment to the landing site REFSMMAT, which occurs immediately after darkness on each of these revolutions. The IMU realignment attitude also sets up the landmark sighting attitude for the next revolution. The IMU realignment attitude is maintained inertially fixed until the CSM becomes pitched 22 degrees below the local horizontal orientation. The inertial attitude hold is then terminated, and a local attitude hold is initiated for the landmark tracking.

In revolution 27, the last of the consecutive landmark tracking revolutions, the CSM is maneuvered to a lunar orbit rest attitude after the completion of landmark tracking on landmark 130. This rest attitude is held inertially fixed through the end of the twenty-seventh revolution. CSM S-band communications are available on each of these revolutions only from the end of landmark tracking on landmark 130 to the loss of MSFN line of sight.

5.3.7 Twenty-eight revolution (Figure 40). - After the completion of the landmark tracking in the twenty-seventh revolution, a 3-1/2 hour rest period is provided for the crew. During this time, no duties are scheduled and the spacecraft is left in an inertial attitude hold. The lunar orbit rest attitude provides CSM S-band HGA communications whenever line of sight to MSFN exists. In addition, the rest attitude allows observation of the lunar surface near the lunar morning terminator, if desired. The lunar orbit rest attitude is maintained inertially fixed throughout the twenty-eighth revolution.

5.3.8 Twenty-ninth revolution (Figure 41). - At the beginning of the twenty-ninth revolution, the CSM is in the inertially fixed lunar orbit rest attitude. Early in the twenty-ninth revolution, the rest period is terminated, and the CSM is maneuvered to the initial attitude for an oblique photography sequence of LS3. The attitude sequence for the oblique photography is the same as that discussed earlier for the oblique photography sequence of LS2 in the twenty-second revolution. At the completion of the oblique photography sequence of LS3, the pitch rate is terminated and the spacecraft is maneuvered to an IMU realignment attitude. This inertially fixed attitude satisfies the requirement for an IMU realignment to the landing site REFSMMAT, which occurs approximately 5 minutes after the CSM enters darkness. This attitude is held inertially fixed until approximately 5 minutes after the loss of MSFN line of sight. The CSM is then maneuvered to the lunar observation attitude for targets of opportunity photography. The CSM attitude, with respect to the local horizontal orientation,

is a pitch of -45 degrees and a roll of 180 degrees. This attitude is maintained locally fixed through the completion of the twenty-ninth revolution. The lunar observation attitude allows photography of the spacecraft groundtrack through the CSM hatch and rendezvous windows and oblique photography through the CSM side windows. CSM S-band HGA communications will be available from the acquisition of MSFN line of sight until loss of MSFN line of sight.

5.3.9 Thirtieth revolution (Figure 42). - At the beginning of the thirtieth revolution, the CSM is in the locally fixed lunar observation attitude. This attitude is maintained locally fixed until approximately 9 minutes after acquisition of MSFN line of sight. The CSM is then maneuvered to the undocked lunar landmark tracking attitude for landmark tracking on B1 and landmark 150. The CSM attitude, with respect to the local horizontal orientation, is a pitch of -22 degrees. This attitude is held locally fixed throughout the two landmark tracking periods. Upon completion of the landmark tracking on landmark 150, the CSM is rolled 180 degrees for communication, and the resulting attitude is held inertially fixed through the completion of the thirtieth revolution. CSM S-band HGA communications will be available from the maneuver after the landmark sighting on landmark 130 to the loss of MSFN line of sight.

5.3.10 Thirty-first revolution (Figure 43). - At the beginning of the thirty-first revolution, the CSM is in an inertially fixed communications attitude. This attitude is maintained until approximately 10 minutes prior to acquisition of MSFN line of sight. The CSM is then maneuvered to the vertical strip photography attitude for descent strip photography. The CSM attitude, with respect to the local horizontal orientation, is a pitch of -102 degrees. This allows the camera optical axis to be pointed vertically down, and the CSM windows to be shaded from the sun during the actual photography. This attitude is held locally fixed during the photography. At 85 degrees east selenographic longitude, the spacecraft is yawed -20 degrees (left) to include a highland site (Censorinus) in the photography. At 30 degrees selenographic longitude, the CSM is yawed 20 degrees (right) to place the camera axis back on the spacecraft ground-track. The strip photography attitude is maintained locally fixed until after the spacecraft crosses the lunar morning terminator. The CSM is then maneuvered to an attitude that is rolled 180 degrees from the TEI burn attitude. This attitude is held inertially fixed. This attitude satisfies the attitude requirements for the IMU realignment to the landing site REFSMMAT, which occurs approximately 14 minutes after the CSM enters into darkness. After the completion of the IMU realignment, the CSM is rolled 180 degrees into the TEI burn attitude. This attitude is held inertially fixed through the completion of the thirty-first revolution. CSM S-band HGA communications will be available from the completion of the strip photography until the maneuver to the TEI burn attitude.

5.3.11 Start of thirty-second revolution (Figure 44). - Shortly after the CSM enters the thirty-second revolution, the TEI burn occurs. The TEI burn is an SPS burn which boosts the CSM from the approximately 60-nautical mile circular lunar orbit into the transearth trajectory. The burn is performed with the CSM in a posigrade attitude, and the crew is heads down to afford visual reference with the lunar surface. The TEI burn ignition occurs at 137:20:22 g. e. t.

6. TRANSEARTH

The transearth phase of the mission begins at TEI burn termination and ends at earth atmospheric entry of the CM. Most of the major events occurring in this phase (midcourse corrections, PTC, IMU realignments, and cislunar navigation) are similar in nature to the translunar coast. Those events unique to the transearth phase, which will be discussed in this section, are the attitude sequences following TEI and prior to entry. The spacecraft attitude data for the transearth coast phase are presented in Table II(d).

6.1 Post-TEI Sequence of Events

Following TEI cutoff at 137:23:11 g. e. t. the CSM maneuvers to an inertial attitude that provides the crew with visual observation of the lunar surface. This orientation consists of the CSM plus X-axis pointing radially inward and the plus Z-axis forward in the trajectory plane. MSFN communications through the HGA at acquisition of signal is also provided with this attitude. Earth line of sight is acquired at 137:29:15 g. e. t. An IMU realignment begins at approximately 138:00:00 g. e. t. during which the IMU reference system is realigned to the PTC REFSMMAT defined in Section 4. The completion of the realignment marks the termination of post-TEI activities.

6.2 Preentry Sequence of Events

The start of the preentry attitude sequence is assumed at 187:30:00 g. e. t. when the spacecraft IMU is aligned to the entry REFSMMAT. This inertial reference system corresponds to the nominal CM entry attitude of 156 degrees positive pitch from the local horizontal at the nominal time of entry with the body X-Z axes in-plane. A midcourse correction is scheduled at 188:50:00 g. e. t., if required. One hour later, at 189:50:00 g. e. t., the CSM orients to the entry attitude and performs a star check to verify the attitude. An IMU realignment is performed at 190:15:00 g. e. t. Upon completion of the realignment, the spacecraft prepares for the CM/SM separation maneuver which occurs at 191:35:00 g. e. t. The CM/SM separation attitude is shown in Figure 45. The spacecraft is yawed 45 degrees for separation to minimize CM-SM recontact probability during entry. After completing the separation maneuver, the CM reorients to the nominal entry attitude in preparation for entry which occurs at 191:50:32 g. e. t. The CM entry attitude is presented in Figure 46.



Table I. Mission F Event Timeline
(a) Translunar

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
02:38:49	TLI cutoff, inertial attitude hold
02:39:09	S-IVB maneuver to local horizontal attitude, local attitude hold
02:53:49	S-IVB maneuver to CSM/S-IVB separation attitude, inertial attitude hold
03:03:49	CSM/S-IVB separation
03:05:49	CSM null separation rate, pitch 180 deg for docking
04:08:49	LM withdrawal
04:28:47	SPS evasive maneuver burn ignition
04:28:50	Evasive maneuver burn cutoff
05:00:00	Begin IMU realignment, change to PTC REFSMMAT
05:30:00	Begin star-earth horizon navigation sightings
11:33:00	SPS midcourse burn ignition for G mission groundtrack
11:40:00	Begin IMU realignment
12:00:00	Begin PTC
24:40:00	Terminate PTC, begin IMU realignment
25:00:00	Begin star-earth horizon navigation sightings
26:30:00	Midcourse correction
27:00:00	Maneuver to S-band reflectivity attitude
28:00:00	Begin PTC
45:00:00	Terminate PTC, begin IMU realignment
45:30:00	Begin PTC at 3 revolutions per hour roll rate without pitch-yaw axis control

Table I. Mission F Event Timeline
(a) Translunar (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
49:30:00	Terminate PTC test, resume normal PTC
53:00:00	Terminate PTC, begin IMU realignment
53:45:00	Midcourse correction
54:30:00	Begin PTC
70:00:00	Terminate PTC, begin IMU realignment, change to landing site REFSMMAT
70:45:00	Midcourse correction
72:00:00	Maneuver to lunar TV attitude, inertial attitude hold
72:35:00	Terminate TV, continue inertial attitude hold
72:47:00	Enter lunar umbra
74:38:00	Enter sunlight
74:45:00	Maneuver to LOI-1 burn attitude, inertial attitude hold
75:38:00	Lose MSFN line of sight
75:45:43	LOI-1 burn ignition

Table I. Mission F Event Timeline
(b) Lunar Orbit

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
75:51:45	LOI-1 cutoff, inertial attitude hold
76:00:00	Roll 180 deg for communications, inertial attitude hold
76:12:05	Acquire MSFN line of sight
76:17:00	Maneuver to lunar observation attitude, local attitude hold
76:55:00	Terminate orbital rate, inertial attitude hold
76:55:06	Enter lunar umbra
77:00:00	Begin IMU realignment
77:20:00	Maneuver to sleep attitude for communications reacquisition test, inertial attitude hold
77:37:18	Lose MSFN line of sight
77:41:42	Enter sunlight
78:20:22	Acquire MSFN line of sight
78:30:00	Roll 45 deg to improve lunar observation near morning terminator, inertial attitude hold
79:03:35	Enter lunar umbra
79:05:00	Begin IMU realignment
79:20:00	Maneuver to LOI-2 burn attitude, inertial attitude hold
79:45:20	Lose MSFN line of sight
79:50:10	Enter sunlight
80:10:46	LOI-2 ignition
80:11:00	LOI-2 cutoff, inertial attitude hold
80:20:00	Roll 180 deg for communications, inertial attitude hold
80:29:54	Acquire MSFN line of sight
80:35:00	Maneuver to lunar observation attitude, local attitude hold
81:00:00	Terminate local hold, inertial attitude hold

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
81:03:30	Enter lunar umbra
81:10:00	Begin IMU realignment
81:41:52	Lose MSFN line of sight
81:45:00	LM occupied
81:49:52	Enter sunlight
81:50:00	Maneuver to landmark tracking attitude for F-1, inertial attitude hold
82:27:45	Time T_1 for F-1
82:27:56	Acquire MSFN line of sight
82:32:45	Time T_2 for F-1, start -0.3 deg/sec pitch rate for landmark tracking on F-1
82:35:45	Terminate pitch rate, inertial attitude hold
82:38:45	Maneuver to landmark tracking attitude for B1, inertial attitude hold
82:44:46	Time T_1 for B1
82:49:46	Time T_2 for B1, start -0.3 deg/sec pitch rate for landmark tracking on B1
82:52:46	Terminate pitch rate, inertial attitude hold
82:55:46	Maneuver to sleep attitude, inertial attitude hold
83:00:00	Deactivate CSM RCS jets B-3, C-4 prior to LM S-band steerable activation
83:02:00	Enter lunar umbra
83:05:00	Start LM communications tests
83:30:00	Terminate LM communications tests
83:40:09	Lose MSFN line of sight
83:48:22	Enter sunlight
83:55:00	LM unoccupied

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
84:26:14	Acquire MSFN line of sight
84:45:00	Start crew sleep period
85:00:30	Enter lunar umbra
85:38:20	Lose MSFN line of sight
85:46:52	Enter sunlight
86:24:36	Acquire MSFN line of sight
86:59:01	Enter lunar umbra
87:36:32	Lose MSFN line of sight
87:45:22	Enter sunlight
88:22:55	Acquire MSFN line of sight
88:57:30	Enter lunar umbra
89:34:49	Lose MSFN line of sight
89:43:51	Enter sunlight
90:20:36	Acquire MSFN line of sight
90:56:01	Enter lunar umbra
91:32:31	Lose MSFN line of sight
91:42:22	Enter sunlight
92:18:51	Acquire MSFN line of sight
92:54:29	Enter lunar umbra
93:00:00	Crew wake-up
93:30:46	Lose MSFN line of sight
93:40:51	Enter sunlight
94:17:07	Acquire MSFN line of sight
94:25:00	LM occupied
94:53:00	Enter lunar umbra
94:55:00	Begin IMU realignment
95:25:00	Maneuver to landmark tracking attitude for 130, inertial attitude hold

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
95:29:05	Lose MSFN line of sight
95:39:21	Enter sunlight
96:15:28	Acquire MSFN line of sight
96:35:39	Time T_1 for 130
96:40:39	Time T_2 for 130, start -0.3 deg/sec pitch rate for landmark tracking on 130
96:43:39	Terminate pitch rate, inertial attitude hold
96:46:39	Maneuver to undocking attitude rolled 180 deg, inertial attitude hold
96:51:30	Enter lunar umbra
97:27:23	Lose MSFN line of sight
97:30:00	Roll 180 deg to undocking attitude, inertial attitude hold
97:37:51	Enter sunlight
97:45:00	AGS calibration maneuvers
97:55:00	LM deploy landing gear
98:10:00	Undocking, inertial attitude hold
98:12:39	LM maneuver to inspection attitude, inertial attitude hold except for 360-deg roll (pilot yaw) maneuver
98:13:24	CSM, LM acquire MSFN line of sight
98:15:39	LM begin station keeping, inertial attitude hold
98:17:09	CSM roll 180 deg for S-band high-gain communications, inertial attitude hold
98:35:16	CSM separation burn ignition, inertial attitude hold
98:35:30	CSM separation burn cutoff
98:39:00	CSM maneuver to SXT tracking - VHF ranging attitude; LM maneuver to RR tracking attitude, line-of-sight maintenance

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
98:49:58	CSM enter lunar umbra
98:50:00	LM enter lunar umbra
98:55:00	CSM, LM begin IMU realignment, inertial attitude hold
99:25:38	CSM lose MSFN line of sight
99:25:39	LM lose MSFN line of sight
99:29:00	LM maneuver to DOI burn attitude, inertial attitude hold
99:33:59	LM DOI burn ignition, inertial attitude hold; CSM maneuver to SXT tracking - VHF ranging attitude, line-of-sight maintenance
99:34:27	DOI burn cutoff, LM maneuver to RR tracking attitude
99:36:18	CSM enter sunlight
99:36:23	LM enter sunlight
99:49:27	LM terminate tracking, maneuver to PDI attitude, inertial attitude hold
100:04:27	CSM roll 180 deg, maneuver to SXT tracking - VHF ranging attitude
100:11:43	CSM acquire MSFN line of sight
100:14:17	LM acquire MSFN line of sight
100:24:37	LM maneuver to LR test attitude, begin -0.055 deg/sec pitch rate (approximate)
100:31:17	Pericynthion of LM descent orbit LM at 0-deg landing site elevation angle
100:41:31	LM enter lunar umbra
100:46:21	DPS phasing burn ignition, CSM monitor burn in SXT tracking - VHF ranging attitude
100:47:03	Phasing burn cutoff, inertial attitude hold
100:48:27	CSM enter lunar umbra

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
100:52:03	CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively
101:02:03	CSM and LM terminate tracking, CSM inertial attitude hold, LM maneuver to IMU realignment attitude, inertial attitude hold
101:17:03	CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively
101:20:47	LM terminate tracking, inertial attitude hold
101:23:52	CSM lose MSFN line of sight
101:25:52	LM lose MSFN line of sight
101:27:03	CSM terminate tracking, inertial attitude hold
101:28:57	LM enter sunlight
101:34:49	CSM enter sunlight
101:48:18	CSM maneuver to SXT tracking attitude
101:59:18	LM maneuver to RR tracking attitude
102:08:18	CSM terminate tracking, maneuver to MI insertion burn attitude, inertial attitude hold
102:09:57	CSM acquire MSFN line of sight
102:14:19	LM acquire MSFN line of sight
102:19:18	LM terminate tracking, maneuver to descent stage jettison attitude, inertial attitude hold
102:33:18	Begin descent stage jettison
102:36:18	Complete descent stage jettison, maneuver to insertion burn attitude, inertial attitude hold
102:43:18	APS insertion burn ignition
102:43:33	Insertion burn cutoff, inertial attitude hold
102:46:58	CSM enter lunar umbra
102:47:58	LM enter lunar umbra
103:01:33	LM maneuver to RR tracking attitude
103:06:33	CSM maneuver to SXT tracking - VHF ranging attitude

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
103:18:33	CSM terminate tracking, maneuver to MI CSI burn attitude, inertial attitude hold
103:22:03	CSM lose MSFN line of sight
103:24:01	LM lose MSFN line of sight
103:24:33	LM terminate tracking, maneuver to CSI burn attitude, inertial attitude hold
103:33:17	CSM enter sunlight
103:33:46	CSI burn ignition (RCS plus X-axis 4 jets)
103:34:18	CSI burn cutoff, inertial attitude hold
103:36:52	LM enter sunlight
103:40:18	CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively
104:08:12	CSM acquire MSFN line of sight
104:11:03	LM acquire MSFN line of sight
104:20:18	CSM and LM terminate tracking, CSM man- euver to MI CDH burn attitude, inertial attitude hold; LM maneuver to CDH burn attitude, inertial attitude hold
104:31:42	CDH burn ignition (RCS minus X-axis 4 jets)
104:31:45	CDH burn cutoff, inertial attitude hold
104:35:45	CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively
104:45:29	CSM enter lunar umbra
104:45:44	LM enter lunar umbra
104:52:34	CSM and LM terminate tracking, CSM man- euver to MI TPI burn attitude, inertial atti- tude hold; LM maneuver to TPI burn attitude, inertial attitude hold

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
105:08:57	TPI burn ignition (RCS plus X-axis 4 jets)
105:09:13	TPI burn cutoff, CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively
105:19:32	LM lose MSFN line of sight
105:20:07	CSM lose MSFN line of sight
105:31:49	CSM enter sunlight
105:32:13	LM enter sunlight
105:50:14	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 3000 ft
105:50:30	Braking burn cutoff, CSM and LM continue tracking
105:51:27	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 1500 ft
105:51:39	Braking burn cutoff, CSM and LM continue tracking
105:53:04	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 500 ft
105:53:10	Braking burn cutoff, CSM and LM continue tracking
105:54:24	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 100 ft
105:54:30	Braking burn cutoff, CSM-LM range = 85 ft, CSM-LM range rate = -0.22 ft/sec
105:57:10	CSM and LM maneuver to docking attitude, CSM-LM range = 50 ft
106:06:33	CSM and LM acquire MSFN line of sight
106:20:00	CSM/LM docking, inertial attitude hold
106:43:56	Enter lunar umbra
106:50:45	Maneuver to LM jettison attitude, inertial attitude hold
107:18:17	Lose MSFN line of sight

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
107:30:17	Enter sunlight
108:04:34	Acquire MSFN line of sight
108:09:24	Complete LM jettison, LM inertial hold in APS burn attitude; CSM evasive maneuver ignition
108:09:29	CSM evasive maneuver cutoff, CSM maneuver to LM observation attitude, inertial attitude hold
108:38:57	LM unmanned APS burn to depletion ignition
108:42:30	Enter lunar umbra
109:00:00	Maneuver to sleep attitude, inertial attitude hold, start crew sleep period
109:16:43	Lose MSFN line of sight
109:28:50	Enter sunlight
110:02:53	Acquire MSFN line of sight
110:40:59	Enter lunar umbra
111:14:55	Lose MSFN line of sight
111:27:19	Enter sunlight
112:01:11	Acquire MSFN line of sight
112:39:30	Enter lunar umbra
113:13:10	Lose MSFN line of sight
113:25:50	Enter sunlight
113:59:30	Acquire MSFN line of sight
114:37:59	Enter lunar umbra
115:11:26	Lose MSFN line of sight
115:24:20	Enter sunlight
115:57:11	Acquire MSFN line of sight
116:36:29	Enter lunar umbra

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
117:09:02	Lose MSFN line of sight
117:22:50	Enter sunlight
117:55:25	Acquire MSFN line of sight
118:00:00	Crew wake-up, maneuver to initial attitude for oblique photography of LS2, local attitude hold
118:19:29	Start 0.5 deg/sec pitch rate for photography of LS2
118:22:04	Terminate pitch rate, inertial attitude hold
118:34:59	Enter lunar umbra
118:55:00	Begin IMU realignment
119:07:21	Lose MSFN line of sight
119:10:00	Maneuver to strip photography attitude, local attitude hold
119:21:19	Enter sunlight
119:53:43	Acquire MSFN line of sight
119:55:00	Maneuver at subsolar point to turn windows away from sun, continue strip photography, local attitude hold
120:06:00	Yaw 20 deg to include LS1, local attitude hold
120:17:00	Yaw -20 deg, adjust attitude, continue strip photography, local attitude hold
120:27:00	Terminate strip photography, maneuver to IMU realignment attitude, inertial attitude hold
120:33:29	Enter lunar umbra
120:35:00	Begin IMU realignment
121:05:40	Lose MSFN line of sight
121:14:00	Maneuver to landmark sighting attitude, local attitude hold

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time (hr:min:sec)</u>	<u>Event</u>
121:19:49	Enter sunlight
121:26:06	Time T_1 for CP_1
121:28:51	Time T_2 for CP_1
121:41:09	Time T_1 for CP_2
121:42:50	Time T_2 for CP_2
121:52:03	Acquire MSFN line of sight
121:53:49	Time T_1 for F-1
121:56:06	Time T_2 for F-1
122:15:14	Time T_1 for 130
122:16:51	Time T_2 for 130
122:19:51	Maneuver to IMU realignment attitude, inertial attitude hold
122:31:59	Enter lunar umbra
122:35:00	Begin IMU realignment
123:03:56	Lose MSFN line of sight
123:13:22	Start local attitude hold for landmark tracking
123:18:19	Enter sunlight
123:24:15	Time T_1 for CP_1
123:27:00	Time T_2 for CP_1
123:39:19	Time T_1 for CP_2
123:41:00	Time T_2 for CP_2
123:49:57	Acquire MSFN line of sight
123:52:00	Time T_1 for F-1
123:54:17	Time T_2 for F-1
124:13:24	Time T_1 for 130
124:15:02	Time T_2 for 130
124:18:02	Maneuver to IMU realignment attitude, inertial attitude hold

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
124:30:28	Enter lunar umbra
124:33:00	Begin IMU realignment
125:02:12	Lose MSFN line of sight
125:11:33	Start local attitude hold for landmark tracking
125:16:49	Enter sunlight
125:22:25	Time T_1 for CP_1
125:25:10	Time T_2 for CP_1
125:37:29	Time T_1 for CP_2
125:39:10	Time T_2 for CP_2
125:48:14	Acquire MSFN line of sight
125:50:10	Time T_1 for F-1
125:52:27	Time T_2 for F-1
126:11:34	Time T_1 for 130
126:13:12	Time T_2 for 130
126:16:12	Maneuver to IMU realignment attitude, inertial attitude hold
126:28:59	Enter lunar umbra
126:30:00	Begin IMU realignment
127:00:27	Lose MSFN line of sight
127:09:43	Start local attitude hold for landmark tracking
127:15:19	Enter sunlight
127:20:35	Time T_1 for CP_1
127:23:21	Time T_2 for CP_1
127:35:39	Time T_1 for CP_2
127:37:20	Time T_2 for CP_2
127:46:32	Acquire MSFN line of sight
127:48:20	Time T_1 for F-1

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
127:50:37	Time T_2 for F-1
128:09:44	Time T_1 for 130
128:11:22	Time T_2 for 130
128:14:20	Maneuver to rest attitude, inertial attitude hold
128:27:28	Enter lunar umbra
128:58:27	Lose MSFN line of sight
129:13:49	Enter sunlight
129:44:51	Acquire MSFN line of sight
130:25:58	Enter lunar umbra
130:56:44	Lose MSFN line of sight
131:12:18	Enter sunlight
131:42:54	Acquire MSFN line of sight
131:55:00	End crew rest period, maneuver to initial attitude for oblique photography of LS3, local attitude hold
132:14:53	Start 0.5 deg/sec pitch rate for photography of LS3
132:17:28	Terminate pitch rate, inertial attitude hold
132:20:28	Maneuver to IMU realignment attitude, inertial attitude hold
132:24:28	Enter lunar umbra
132:30:00	Begin IMU realignment
132:55:01	Lose MSFN line of sight
133:00:00	Maneuver to attitude for photo targets of opportunity, local attitude hold
133:10:49	Enter sunlight
133:41:11	Acquire MSFN line of sight
133:50:00	Maneuver to landmark sighting attitude, local attitude hold

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
134:00:27	Time T_1 for B1
134:02:15	Time T_2 for B1
134:12:38	Time T_1 for 150
134:14:08	Time T_2 for 150
134:17:08	Roll 180 deg for communications, inertial attitude hold
134:22:57	Enter lunar umbra
134:53:13	Lose MSFN line of sight
135:09:18	Enter sunlight
135:30:00	Maneuver to strip photography attitude, local attitude hold
135:39:29	Acquisition of MSFN line of sight
135:45:23	Yaw -20 deg to include highland site, local attitude hold
136:03:30	Yaw 20 deg, adjust attitude, continue strip photography, local attitude hold
136:20:00	Maneuver to TEI attitude, rolled 180 deg, inertial attitude hold
136:21:28	Enter lunar umbra
136:35:00	Begin IMU realignment
136:45:00	Roll 180 deg to TEI burn attitude, inertial attitude hold
136:51:28	Lose MSFN line of sight
137:07:48	Enter sunlight
137:20:22	TEI burn ignition

Table I. Mission F Event Timeline
(c) Transearth

<u>Mission Time</u> <u>(hr:min:sec)</u>	<u>Event</u>
137:23:11	TEI cutoff, maneuver to lunar surface observation attitude (CSM plus X-axis down and plus Z-axis forward), inertial attitude hold
137:29:15	Acquire MSFN
138:00:00	Begin IMU realignment, change to PTC REFSMMAT
138:30:00	Begin PTC
150:30:00	Terminate PTC, begin IMU realignment
151:00:00	Begin star-lunar landmark navigation sightings
152:20:00	Midcourse correction
152:45:00	Begin PTC
165:00:00	Terminate PTC, begin IMU realignment
165:20:00	Begin star-earth horizon navigation sightings
165:45:00	Begin PTC at 3 revolutions per hour roll rate without pitch-yaw axis control
169:45:00	Terminate PTC test, resume normal PTC
171:00:00	Terminate PTC, begin star-earth horizon navigation sightings
171:30:00	Begin PTC
174:30:00	Terminate PTC, begin star-earth horizon navigation sightings
175:30:00	Begin IMU realignment
176:50:00	Midcourse correction
177:15:00	Begin PTC
187:30:00	Terminate PTC, begin IMU realignment, change to entry REFSMMAT
188:50:00	Midcourse correction
189:50:00	Maneuver to entry attitude, inertial attitude hold
190:15:00	Begin IMU realignment
191:35:00	CM/SM separation
191:50:32	Entry interface

Table II. Mission F Spacecraft Attitude Data
(a) Earth Orbit

Mission Time (hr:min:sec)	Event	Geographic Position			Local Horizontal			IMU Gimbal Angles		
		Altitude* (n mi)	Latitude* (deg)	Longitude* (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)
00:11:24	Earth orbit insertion, begin inertial attitude hold	103.4	32.8	-54.2	0.0	0.0	180.0	-25.4	0.6	-179.4
00:11:44	Begin local attitude hold	103.4	32.8	-54.7	0.0	0.0	180.0	-25.9	0.6	-179.4
02:33:27	Initiate TLI burn	99.2	-25.4	136.0	0.0	0.0	180.0	114.1	-0.3	178.9

* Altitude is measured with respect to the Fischer reference ellipsoid; latitude and longitude are measured positive north of the equator and east from the Greenwich meridian, respectively.

Table II. Spacecraft Attitude and Trajectory Data
(b) Translunar

Mission Time (hr:min:sec)	Event	IMU Gimbal Angles			Look Angles to Earth		Look Angles to Moon		Look Angles to Sun	
		IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
02:38:49	TLI cutoff (inertial attitude hold not simulated)	88.0	1.5	179.0	90.0	180.0	30.7	-6.2	9.4	-75.3
02:39:09	S-IVB maneuver to local horizontal, local attitude hold	87.0	1.5	179.0	90.0	180.0	30.7	-6.2	9.4	-75.3
02:53:49	S-IVB maneuver to CSM/S-IVB separation attitude, inertial attitude hold	150.7	39.8	-2.3	131.6	48.1	89.7	176.4	64.0	-169.6
03:03:49	CSM/S-IVB separation	150.7	39.8	-2.3	120.6	29.8	89.7	176.0	64.0	-169.6
03:05:49	CSM null separation rate, pitch 180 deg and roll 60 deg left for docking	-29.3	-39.8	-57.6	60.5	-149.8	90.2	64.0	115.9	50.4
04:08:49	LM withdrawal	-29.3	-39.8	-57.6	86.8	27.7	90.5	64.0	115.9	50.3
04:28:47	SPS evasive maneuver burn ignition	-108.7	-1.6	60.7	15.0	120.0	161.1	-49.4	166.6	77.1
04:28:50	Evasive maneuver burn cutoff	-108.7	-1.6	60.7	15.0	120.0	161.1	-49.4	166.6	77.1
05:00:00	Begin IMU realignment, change to PTC REFSMMAT	Maneuver spacecraft as required								
05:30:00	Begin star-earth horizon navigation sightings	Maneuver spacecraft as required								
11:33:00	SPS midcourse burn for G mission groundtrack	Maneuver spacecraft as required								
11:40:00	Begin IMU realignment	-90.0	0.0	0.0	83.5	-44.5	94.5	156.2	90.0	180.0
12:00:00	Begin PTC	Maneuver spacecraft as required								
24:40:00	Terminate PTC, begin IMU realignment	Maneuver spacecraft as required								
25:00:00	Begin star-earth horizon navigation sightings	Maneuver spacecraft as required								

Table II. Spacecraft Attitude and Trajectory Data
(b) Translunar (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angles			Look Angles to Earth		Look Angles to Moon		Look Angles to Sun	
		IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
26:30:00	Midcourse correction	Maneuver spacecraft as required								
27:00:00	Maneuver to S-band reflectivity test attitude	-36.2	-41.5	71.5	22.3	-117.3	145.0	138.5	126.0	151.5
28:00:00	Begin PTC	-90.0	0.0	0.0	84.8	-55.2	94.3	160.9	90.0	-178.6
45:00:00	Terminate PTC, begin IMU realignment	Maneuver spacecraft as required								
45:30:00	Begin PTC at 3 revolutions per hour roll rate without pitch-yaw axis control	-90.0	0.0	0.0	85.3	-59.0	94.3	164.0	90.0	-179.2
49:30:00	Terminate PTC tests, resume normal PTC	-90.0	0.0	-90.0	85.5	30.2	94.3	-105.1	90.0	-89.5
53:00:00	Terminate PTC, begin IMU realignment	Maneuver spacecraft as required								
53:45:00	Midcourse correction	Maneuver spacecraft as required								
54:30:00	Begin PTC	-90.0	0.0	90.0	85.5	-150.2	94.3	75.4	90.0	90.4
70:00:00	Terminate PTC, begin IMU realignment, change to landing site REFMMAT	Maneuver spacecraft as required								
70:45:00	Midcourse correction	Maneuver spacecraft as required								
72:00:00	Maneuver to lunar TV attitude, inertial attitude hold	128.2	2.1	173.7	167.9	24.1	45.0	0.0	49.8	7.0
72:35:00	Terminate TV, continue inertial attitude hold	128.2	2.1	173.7	167.9	24.1	46.3	0.0	49.8	7.0
72:47:00	Enter lunar umbra	128.2	2.1	173.7	167.9	24.1	47.2	0.0	No line of sight	
74:38:00	Enter sunlight	128.2	2.1	173.7	168.0	24.1	62.0	0.0	49.7	7.0
74:45:00	Maneuver to LOI-1 burn attitude, inertial attitude hold	-128.5	-19.9	-4.1	86.4	-0.7	161.8	-130.3	147.4	-143.3
75:38:00	Lose MSFN line of sight	-128.5	-19.9	-4.1	No line of sight		129.0	-1.5	147.3	-143.3
75:45:43	LOI-1 burn ignition	-128.5	-19.9	-4.1	No line of sight		107.0	-0.7	147.3	-143.3

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit
Part 1: LOI-1 Cutoff to CSM/LM Undocking

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Optics Angles to Landmark	
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Shaft (deg)	Trunnion (deg)
75:51:45	LOI-1 cutoff, inertial attitude hold	58.2	0.2	172.6	-173.4	-20.1	-3.6	-128.1	-20.1	-3.6	No line of sight		147.3	-142.3		
76:00:00	Roll 180 deg for communications, inertial attitude hold	60.7	0.7	146.9	-147.7	-20.1	176.4	-128.1	-20.1	176.4	No line of sight		147.3	37.7		
76:12:05	Acquire MSFN line of sight	80.4	1.2	109.9	-111.1	-20.1	176.4	-128.1	-20.1	176.4	85.6	179.4	147.3	37.7		
76:17:00	Maneuver to lunar observation attitude, local attitude hold	92.2	1.2	95.4	-45.0	0.0	180.0	-76.7	0.0	180.0	36.2	170.7	155.2	-179.4		
76:55:00	Terminate orbital rate, inertial attitude hold	167.6	-0.1	-6.6	-45.0	0.0	180.0	-178.4	0.0	180.0	137.9	171.8	103.1	-0.3		
76:55:06	Enter lunar umbra	167.6	-0.1	-6.9	-44.7	0.0	180.0	-178.4	0.0	180.0	137.9	171.8	No line of sight			
77:00:00	Begin IMU realignment	167.9	-0.4	-19.3	-33.3	0.0	180.0	-178.4	0.0	180.0	137.9	171.8	No line of sight			
77:20:00	Maneuver to sleep attitude for communications reacquisition test, inertial attitude hold	141.4	-1.2	-70.9	45.5	0.0	135.0	-152.0	0.0	135.0	112.1	-140.9	No line of sight			
77:37:18	Lose MSFN line of sight	96.8	-1.1	-119.0	93.2	0.0	135.0	-152.0	0.0	135.0	No line of sight		No line of sight			
77:41:42	Enter sunlight	85.7	-0.9	-131.8	106.0	0.0	135.0	-152.0	0.0	135.0	No line of sight		129.4	44.7		
78:20:22	Acquire MSFN line of sight	79.9	1.2	109.4	-135.5	0.0	135.0	-152.0	0.0	135.0	112.1	-140.8	129.4	44.7		
78:30:00	Roll 45 deg to improve lunar observation near morning terminator, inertial attitude hold	103.9	1.2	81.3	-107.4	0.0	180.0	-152.0	0.0	180.0	112.1	174.2	129.4	-0.3		
79:03:35	Enter lunar umbra	167.6	-0.1	-8.0	-18.4	0.0	180.0	-152.0	0.0	180.0	112.7	174.1	No line of sight			
79:05:00	Begin IMU realignment	167.9	-0.3	-11.4	-14.8	0.0	180.0	-152.0	0.0	180.0	112.8	174.1	No line of sight			
79:20:00	Maneuver to LOI-2 burn attitude, inertial attitude hold	157.7	-0.9	-49.8	36.7	-2.4	0.1	-138.5	-2.4	0.1	99.4	-6.0	No line of sight			
79:45:20	Lose MSFN line of sight	98.2	-1.1	-118.7	104.5	-2.4	0.1	-138.5	-2.4	0.1	No line of sight		No line of sight			
79:50:10	Enter sunlight	86.3	-0.9	-132.9	119.4	-2.4	0.1	-138.5	-2.4	0.1	No line of sight		142.7	-177.4		
80:10:46	LOI-2 ignition	57.9	0.3	164.0	-177.6	-2.4	0.1	-138.5	-2.4	0.1	No line of sight		142.7	-177.4		
80:11:00	LOI-2 cutoff, inertial attitude hold	57.9	0.3	163.3	-176.9	-2.4	0.1	-138.5	-2.4	0.1	No line of sight		142.7	-177.4		
80:20:00	Roll 180 deg for communications, inertial attitude hold	57.9	0.8	135.9	-149.5	-2.4	-179.9	-138.5	-2.4	-179.9	No line of sight		142.7	2.6		
80:29:54	Acquire MSFN line of sight	57.9	1.2	105.7	-119.5	-2.4	-179.9	-138.5	-2.4	-179.9	99.5	174.0	142.7	2.6		
80:35:00	Maneuver to lunar observation attitude, local attitude hold	57.9	1.2	90.2	-45.0	0.0	180.0	-79.5	0.0	180.0	41.1	171.8	158.2	-179.3		
81:00:00	Terminate local hold, inertial attitude hold	57.8	0.4	14.0	-45.0	0.0	180.0	-155.4	0.0	180.0	117.0	174.0	125.8	-0.3		
81:03:30	Enter lunar umbra	57.8	0.1	3.4	-34.4	0.0	180.0	-155.4	0.0	180.0	117.2	174.0	No line of sight			
81:10:00	Begin IMU realignment	57.8	-0.1	-7.2	-14.1	0.0	180.0	-155.4	0.0	180.0	117.3	174.0	No line of sight			
81:41:52	Lose MSFN line of sight	57.8	-1.2	-113.5	82.5	0.0	180.0	-155.4	0.0	180.0	No line of sight		No line of sight			
81:45:00	LM occupied	57.8	-1.1	-123.1	91.7	0.0	180.0	-155.4	0.0	180.0	No line of sight		No line of sight			
81:49:52	Enter sunlight	57.8	-0.9	-137.9	106.9	0.0	180.0	-155.4	0.0	180.0	No line of sight		125.8	-0.3		
81:50:00	Maneuver to landmark tracking attitude for F-1, inertial attitude hold	57.8	-0.9	-138.3	-131.9	0.0	0.0	-34.2	0.0	0.0	No line of sight		113.0	0.3		
82:27:56	Acquire MSFN line of sight	57.9	1.2	106.1	-16.6	0.0	0.0	-34.2	0.0	0.0	6.4	-123.2	113.0	0.3		

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 1: LOI-1 Cutoff to CSM/LM Undocking

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Optics Angles to Landmark	
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Shaft (deg)	Trunnion (deg)
82:32:45	Start -0.3 deg/sec pitch rate for land- mark tracking on F-1	57.9	1.2	91.5	-2.1	0.0	0.0	-34.2	0.0	0.0	6.3	-123.0	113.0	0.3	10.1	20.3
82:35:45	Terminate pitch rate, inertial attitude hold	57.9	1.2	82.3	-47.0	0.0	0.0	-88.3	0.0	0.0	50.8	-6.9	167.1	1.2	174.2	36.9
82:38:45	Maneuver to landmark tracking attitude for B1, inertial attitude hold	57.9	1.2	73.2	-35.5	0.0	0.0	-85.9	0.0	0.0	48.5	-7.1	164.7	1.0		
82:49:46	Start -0.3 deg/sec pitch rate for land- mark tracking on B1	57.8	0.8	39.6	-2.1	0.0	0.0	-85.9	0.0	0.0	48.6	-7.1	164.7	1.0	42.1	24.9
82:52:46	Terminate pitch rate, inertial attitude hold	57.8	0.7	30.5	-47.0	0.0	0.0	-139.9	0.0	0.0	102.5	-5.5	141.3	179.6	153.5	39.2
82:55:46	Maneuver to sleep attitude, inertial attitude hold	57.8	0.5	21.3	-49.9	0.0	0.0	-152.0	0.0	0.0	114.5	-140.9	129.2	44.7		
83:02:00	Enter lunar umbra	57.8	0.1	2.3	-29.5	0.0	0.0	-152.0	0.0	0.0	114.6	-140.9	No line of sight	No line of sight		
83:05:00	Start LM communications tests	57.8	0.1	-6.8	-21.8	0.0	0.0	-152.0	0.0	0.0	114.7	-140.9	No line of sight	No line of sight		
83:30:00	Terminate LM communications tests	57.7	-1.2	-83.0	54.1	0.0	0.0	-152.0	0.0	0.0	115.2	-140.9	No line of sight	No line of sight		
83:40:09	Lose MSFN line of sight	57.8	-1.2	-113.9	94.4	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
83:48:22	Enter sunlight	57.8	-0.9	-138.9	109.7	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.2	44.7		
83:55:00	LM unoccupied	57.8	-0.5	-159.1	130.0	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.2	44.7		
84:26:14	Acquire MSFN line of sight	57.9	1.2	105.7	-135.1	0.0	0.0	-152.0	0.0	0.0	115.1	-140.8	129.2	44.7		
84:45:00	Start crew sleep period	57.8	1.0	48.6	-78.1	0.0	0.0	-152.0	0.0	0.0	115.3	-140.8	129.2	44.7		
85:00:30	Enter lunar umbra	57.8	0.1	1.3	-31.1	0.0	0.0	-152.0	0.0	0.0	115.6	-140.9	No line of sight	No line of sight		
85:38:20	Lose MSFN line of sight	57.8	-1.2	-114.0	83.0	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.1	44.7		
85:46:52	Enter sunlight	57.8	-0.9	-139.9	109.8	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.1	44.7		
86:24:36	Acquire MSFN line of sight	57.9	1.2	105.1	-135.6	0.0	0.0	-152.0	0.0	0.0	116.1	-140.8	129.1	44.7		
86:59:01	Enter lunar umbra	57.8	0.1	0.3	-31.1	0.0	0.0	-152.0	0.0	0.0	116.6	-140.9	No line of sight	No line of sight		
87:36:32	Lose MSFN line of sight	57.7	-1.2	-114.1	82.9	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
87:45:22	Enter sunlight	57.8	-0.9	-141.0	109.7	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.0	44.7		
88:22:55	Acquire MSFN line of sight	57.7	1.2	104.7	-136.2	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.0	44.7		
88:57:30	Enter lunar umbra	57.8	-1.2	-114.4	81.9	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
89:34:47	Lose MSFN line of sight	57.7	-1.2	-141.9	107.0	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	129.0	44.0		
89:41:51	Enter sunlight	57.8	-0.9	-141.9	107.0	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	128.9	44.6		
90:20:36	Acquire MSFN line of sight	57.9	1.1	105.1	-136.7	0.0	0.0	-152.0	0.0	0.0	118.0	-140.8	No line of sight	No line of sight		
90:56:01	Enter lunar umbra	57.8	0.1	-1.7	-31.2	0.0	0.0	-152.0	0.0	0.0	118.6	-140.8	No line of sight	No line of sight		
91:32:31	Lose MSFN line of sight	57.7	-1.2	-112.4	79.6	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	128.9	44.6		
91:47:22	Enter sunlight	57.8	-0.9	-143.6	104.5	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	128.8	44.6		
92:16:51	Acquire MSFN line of sight	57.7	1.1	105.9	-134.6	0.0	0.0	-152.0	0.0	0.0	119.0	-140.8	No line of sight	No line of sight		
92:54:27	Enter lunar umbra	57.8	0.1	-2.7	-31.3	0.0	0.0	-152.0	0.0	0.0	119.6	-140.8	No line of sight	No line of sight		
93:00:00	Crew wake-up	57.8	-0.2	-19.5	-14.6	0.0	0.0	-152.0	0.0	0.0	119.7	-140.8	No line of sight	No line of sight		
93:30:46	Lose MSFN line of sight	57.7	-1.2	-113.2	78.7	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	128.8	44.6		
93:40:51	Enter Sunlight	57.8	-0.9	-143.9	104.5	0.0	0.0	-152.0	0.0	0.0	No line of sight	No line of sight	124.8	44.6		
94:17:07	Acquire MSFN line of sight	57.9	1.1	105.6	-141.0	0.0	0.0	-152.0	0.0	0.0	120.0	-140.8	128.5	44.6		
94:27:37	LM occupied	57.7	1.2	81.3	-116.5	0.0	0.0	-152.0	0.0	0.0	120.0	-140.8	128.5	44.6		

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 1: LOI-1 Cutoff to CSM/LM Undocking

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Optics Angles to Landmark	
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	TGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Shaft (deg)	Trunnion (deg)
94:53:00	Enter lunar umbra	57.8	0.1	-3.8	-31.4	0.0	135.0	-152.0	0.0	135.0	120.6	-140.8	No line of sight	No line of sight		
94:55:00	Begin IMU realignment	57.9	0.1	-9.8	-25.4	0.0	135.0	-152.0	0.0	135.0	120.6	-140.8	No line of sight	No line of sight		
95:25:00	Maneuver to landmark tracking attitude for 130, inertial attitude hold	57.7	-1.2	-101.2	128.1	0.0	0.0	-89.7	0.0	0.0	59.0	-5.8	No line of sight	No line of sight		
95:29:05	Lose MSFN line of sight	57.7	-1.2	-113.7	140.5	0.0	0.0	-89.7	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
95:39:21	Enter sunlight	57.8	-0.9	-145.0	171.7	0.0	0.0	-89.7	0.0	0.0	No line of sight	No line of sight	169.0	140.1		
96:15:28	Acquire MSFN line of sight	57.9	1.1	105.0	-79.6	0.0	0.0	-89.7	0.0	0.0	59.0	-5.8	169.0	140.7		
96:40:39	Start -0.3 deg/sec pitch rate for landmark tracking on 130	57.8	0.8	28.3	-2.1	0.0	0.0	-89.7	0.0	-0.0	59.2	-5.8	169.0	140.1	15.5	21.0
96:43:39	Terminate pitch rate, inertial attitude hold	57.8	0.6	19.2	-47.0	0.0	0.0	-143.6	0.0	0.0	113.1	-5.4	137.0	179.6	170.6	36.9
96:46:39	Maneuver to undocking attitude rolled 180 deg, inertial attitude hold	57.8	0.4	10.0	120.1	0.0	0.0	14.3	0.0	0.0	45.0	-173.0	65.0	0.3		
96:51:30	Enter lunar umbra	57.8	0.1	-4.7	135.0	0.0	0.0	14.3	0.0	0.0	45.0	-173.0	No line of sight	No line of sight		
97:27:23	Lose MSFN line of sight	57.7	-1.2	-114.1	-116.1	0.0	0.0	14.3	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
97:30:00	Roll 180 deg to undocking attitude, inertial attitude hold	57.8	-1.2	-122.0	-108.2	0.0	180.0	14.3	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight		
97:37:51	Enter sunlight	57.8	-0.9	-146.0	-84.1	0.0	180.0	14.3	0.0	180.0	No line of sight	No line of sight	65.0	-179.7		
97:45:00	ACS calibration maneuvers	57.8	-0.5	-167.7	-62.6	0.0	180.0	14.3	0.0	180.0	No line of sight	No line of sight	65.0	-179.7		
97:55:00	LM deploy landing gear	57.9	0.2	161.8	-32.3	0.0	180.0	14.3	0.0	180.0	No line of sight	No line of sight	65.0	-179.7		
98:10:00	CSM/LM undocking	57.9	1.0	116.1	13.3	0.0	180.0	14.3	0.0	180.0	No line of sight	No line of sight	65.1	-179.7		

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit
Part 2: CSM/LM Undocking to LM APS Burn to Depletion

Mission Time (hr:min:sec)	Event	Vehicle	Selenographic Position			Local Horizontal Attitude			IMU Gimbal Angles			Look Angles to Earth		Look Angles to Sun		Look Angles to Other Vehicle	
			Altitude (nm)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	ICA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
98:10:00	Undocking, inertial attitude hold	CSM	57.9	1.0	116.1	13.3	0.0	180.0	14.3	0.0	180.0	No line of sight	65.1	-179.7	0.0	0.0	0.0
		LM	57.9	1.0	116.1	-166.7	0.0	120.0	-165.7	0.0	120.0	No line of sight	114.9	59.7	0.0	0.0	0.0
98:12:39	LM maneuver to inspection attitude, continue inertial attitude hold except for 360 deg roll (pitch yaw) maneuver	CSM	57.9	1.1	108.0	21.3	0.0	180.0	14.3	0.0	180.0	No line of sight	65.1	-179.7	4.1	-0.3	180.0
		LM	57.9	1.1	108.0	-68.7	0.0	0.0	-75.7	0.0	0.0	No line of sight	155.1	0.6	94.0	180.0	0.0
98:13:24	CSM, LM acquires MSFN line of sight	CSM	57.9	1.1	105.7	23.6	0.0	180.0	14.3	0.0	180.0	44.4	7.0	65.1	-179.7	5.6	0.0
		LM	57.9	1.1	105.7	-66.4	0.0	90.0	-75.7	0.0	90.0	46.0	-96.8	155.1	-89.4	95.6	90.0
98:15:39	LM begin station keeping, continue inertial attitude hold	CSM	57.9	1.2	98.9	30.5	0.0	180.0	14.3	0.0	180.0	44.4	7.0	65.1	-179.7	9.9	0.1
		LM	57.9	1.2	98.9	-59.6	0.0	0.0	-75.7	0.0	0.0	46.0	-6.8	155.1	0.6	99.9	180.0
98:17:01	CSM roll 180 deg for RGA communications, inertial attitude hold	CSM	57.9	1.2	94.3	35.0	0.0	0.0	14.3	0.0	0.0	44.4	-173.0	65.1	0.3	12.3	-179.9
		LM	57.9	1.2	94.3	-55.0	0.0	0.0	-75.7	0.0	0.0	46.0	-6.8	155.1	0.6	102.3	180.0
98:35:16	CMS separation burn ignition, inertial attitude hold	CSM	57.9	1.0	39.2	90.0	0.0	0.0	14.3	0.0	0.0	44.4	-173.0	65.1	0.3	7.2	-179.9
		LM	57.9	1.0	39.2	0.0	0.0	0.0	-75.7	0.0	0.0	46.2	-6.8	155.1	0.6	97.2	180.0
98:35:30	CSM separation burn cutoff	CSM	57.9	0.9	38.4	90.7	0.0	0.0	14.3	0.0	0.0	44.2	-173.0	65.1	0.3	4.9	-179.9
		LM	57.9	0.9	38.4	0.7	0.0	0.0	-75.7	0.0	0.0	46.2	-6.8	155.1	0.6	94.9	180.0
98:39:00	CMS maneuver to SXT tracking - VHF ranging attitude; LM maneuver to RR tracking attitude, line-of-sight maintenance	CSM	57.8	0.8	27.8	136.1	0.0	0.0	49.1	0.0	0.0	78.7	-175.0	30.3	0.6	35.0	180.0
		LM	57.9	0.8	27.8	11.1	0.0	0.0	-75.9	0.0	0.0	46.5	-6.8	155.3	0.7	90.0	180.0
98:44:58	CSM enter lunar umbra	CSM	57.5	0.1	-5.7	164.4	0.0	0.0	44.1	0.0	0.0	73.5	-174.9	No line of sight	No line of sight	35.0	180.0
		LM	57.8	0.1	-5.7	39.4	0.0	0.0	-80.9	0.0	0.0	51.8	-6.2	160.4	0.8	90.0	180.0
98:50:00	LM enter lunar umbra	CSM	57.5	0.1	-5.7	164.5	0.0	0.0	44.0	0.0	0.0	73.4	-174.9	No line of sight	No line of sight	35.0	180.0
		LM	57.8	0.1	-5.7	39.5	0.0	0.0	-81.0	0.0	0.0	51.8	-6.2	No line of sight	No line of sight	90.0	180.0
98:55:00	CSM, LM begin IMI realignment, inertial attitude hold	CSM	57.4	-0.2	-21.0	174.3	0.0	0.0	38.6	0.0	0.0	67.4	-174.7	No line of sight	No line of sight	35.0	180.0
		LM	57.8	-0.2	-21.0	47.3	0.0	0.0	-86.4	0.0	0.0	57.3	-5.8	No line of sight	No line of sight	90.0	180.0
99:25:36	CSM lose MSFN line of sight	CSM	57.5	-1.2	-114.4	-92.6	0.0	0.0	38.6	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	149.1	180.0
		LM	57.8	-1.2	-114.4	142.3	0.0	0.0	-86.4	0.0	0.0	57.7	-5.7	No line of sight	No line of sight	94.1	180.0
99:25:37	LM lose MSFN line of sight	CSM	57.5	-1.2	-114.4	-92.6	0.0	0.0	38.6	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	149.1	180.0
		LM	57.8	-1.2	-114.4	142.4	0.0	0.0	-86.4	0.0	0.0	57.3	-5.8	No line of sight	No line of sight	90.0	180.0
99:29:00	LM maneuver to DOI burn attitude, inertial attitude hold	CSM	57.6	-1.1	-124.7	-112.8	0.0	0.0	8.1	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	71.2	180.0
		LM	57.8	-1.1	-124.7	144.9	0.0	0.0	-74.0	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	169.1	180.0
99:33:59	LM DOI burn ignition, inertial attitude hold; CSM maneuver to SXT tracking - VHF ranging attitude, line-of-sight maintenance	CSM	57.8	-1.0	-134.9	-145.0	0.0	0.0	-34.2	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	35.3	180.0
		LM	57.8	-1.0	-134.8	160.0	0.0	0.0	-74.0	0.0	0.5	No line of sight	No line of sight	No line of sight	No line of sight	179.6	0.0
99:34:27	DOI burn cutoff, LM maneuver to RR tracking attitude	CSM	57.8	-1.0	-141.3	-145.0	0.0	0.0	-40.5	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	35.0	180.0
		LM	57.8	-1.0	-141.2	89.9	0.0	0.0	-165.5	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	90.0	180.0
99:36:18	CSM enter sunlight	CSM	57.8	-0.9	-147.4	-141.0	0.0	0.0	-42.6	0.0	0.0	No line of sight	No line of sight	122.1	0.3	35.0	180.0
99:36:23	LM enter sunlight	LM	57.8	-0.9	-147.2	63.8	0.0	0.0	-117.6	0.0	0.0	No line of sight	No line of sight	112.9	173.7	90.0	180.0
99:49:27	LM terminate tracking, maneuver to PDI attitude, inertial attitude hold	CSM	58.2	-0.1	173.0	-173.0	0.0	0.0	0.0	0.0	0.0	No line of sight	No line of sight	117.9	0.3	35.0	180.0
		LM	49.7	-0.1	173.5	45.6	0.0	180.0	105.0	0.0	180.0	No line of sight	No line of sight	2.5	-0.6	1.6	179.8
100:04:27	CSM roll 180 deg, maneuver to SXT tracking - VHF ranging attitude	CSM	58.4	0.8	127.4	-165.4	0.0	180.0	-42.0	0.0	180.0	No line of sight	No line of sight	171.5	-178.2	35.0	180.0
		LM	30.5	0.8	127.8	92.2	0.0	180.0	105.0	0.0	180.0	No line of sight	No line of sight	2.5	-0.6	18.0	180.0
100:11:43	CSM acquire MSFN line of sight	CSM	58.2	1.1	105.3	-85.2	0.0	180.0	-46.1	0.0	180.0	67.3	174.2	175.6	-176.6	35.0	180.0
100:14:17	LM acquire MSFN line of sight	LM	17.4	1.2	65.1	124.0	0.0	180.0	105.9	0.0	180.0	133.5	6.6	25.5	-0.6	11.5	180.0
100:24:37	LM maneuver to RR tracking attitude, begin 360 deg roll (pitch yaw) (approximate)	CSM	58.1	1.2	105.7	-68.7	0.0	180.0	-115.8	0.0	180.0	87.0	175.2	164.7	-1.0	35.0	180.0
		LM	58.4	1.2	105.7	136.0	0.0	0.0	47.2	0.0	0.5	78.0	-175.0	32.3	0.5	52.0	0.0

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 2: CSM/LM Undocking to LM APS Burn to Depletion

Mission Time (hr:min:sec)	Event	Vehicle	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Look Angles to Other Vehicle	
			Altitude (n.mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
100:31:17	Pericynthion of LM descent orbit	CSM LM	57.9 6.5	1.0 1.0	45.7 38.8	-62.1 90.0	0.0 0.0	180.0 0.0	-130.2 15.0	0.0 0.0	180.0 0.0	101.4 43.8	175.1 -174.0	150.3 64.5	-0.5 0.3	35.0 69.8	180.0 0.0
100:33:45	LM at 0 deg landing site elevation angle, begin landing site observation	CSM LM	57.8 6.8	1.0 0.8	38.1 30.4	-60.3 90.0	0.0 0.0	180.0 0.0	-135.9 6.7	0.0 0.0	180.0 0.0	107.1 35.7	174.9 -171.7	144.6 72.7	-0.4 0.3	35.0 72.4	180.0 0.0
100:34:37	LM terminate LR test, inertial attitude hold	CSM LM	57.8 7.0	0.9 0.8	35.5 27.6	-59.7 90.0	0.0 0.0	180.0 0.0	-137.9 3.9	0.0 0.0	180.0 0.0	109.2 32.8	174.9 -171.0	142.6 75.6	-0.4 0.3	35.0 73.2	180.0 0.0
100:38:21	LM maneuver to phasing burn attitude, inertial attitude hold	CSM LM	57.8 8.5	0.8 0.6	24.3 15.7	-57.5 2.2	0.0 0.0	180.0 0.0	-146.4 -96.1	0.0 0.0	180.0 0.0	117.6 67.7	174.5 -5.2	134.1 175.6	-0.4 3.6	35.0 167.6	180.0 0.0
100:41:31	LM enter lunar umbra	LM	10.7	0.4	4.2	121.1	0.0	0.0	-96.1	0.0	0.0	67.7	-5.2	No line of sight	No line of sight	156.9	0.0
100:46:21	DPS phasing burn ignition, CSM monitor burn in SXT tracking - VHF ranging attitude	CSM LM	57.5 15.2	0.3 0.0	-0.2 -11.2	-53.2 28.8	0.0 0.0	180.0 0.0	-167.0 -96.1	0.0 0.0	180.0 0.0	138.4 67.8	172.7 -5.2	113.5 No line of sight	-0.3 No line of sight	35.0 144.1	180.0 0.0
100:47:03	Phasing burn cutoff, inertial attitude hold	CSM LM	57.5 16.2	0.2 0.0	-2.4 -13.6	-52.8 31.1	0.0 0.0	180.0 0.0	-168.8 -96.1	0.0 0.0	180.0 0.0	140.1 67.9	172.4 -5.2	111.7 No line of sight	-0.3 No line of sight	35.0 142.3	180.0 0.0
100:48:27	CSM enter lunar umbra	CSM	57.4	0.1	-6.7	-52.0	0.0	180.0	-168.8	0.0	180.0	140.1	172.4	No line of sight	No line of sight	35.0	180.0
100:52:03	CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively	CSM LM	57.4 29.6	-0.1 -0.3	-17.6 -30.2	-48.6 89.0	0.0 0.0	180.0 0.0	-179.8 -54.8	0.0 0.0	180.0 0.0	151.1 27.0	169.9 169.3	No line of sight	No line of sight	35.0	180.0
101:02:03	CSM and LM terminate tracking, inertial attitude hold, LM maneuver to IMU realignment attitude, inertial attitude hold	CSM LM	57.3 69.2	-0.7 -0.9	-48.1 -61.8	-39.0 99.7	0.0 0.0	180.0 0.0	159.4 -75.6	0.0 0.0	180.0 0.0	171.1 47.8	146.9 173.5	No line of sight	No line of sight	35.0	180.0
101:17:03	CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively	CSM LM	57.4 136.5	-1.2 -1.2	-93.8 -104.3	-17.7 117.8	0.0 0.0	180.0 0.0	135.1 -99.9	0.0 0.0	180.0 0.0	162.3 72.1	16.0 175.0	No line of sight	No line of sight	35.0	180.0
101:20:47	LM terminate tracking, inertial attitude hold	CSM LM	57.4 151.0	-1.2 -1.2	-105.2 -114.2	-9.6 124.3	0.0 0.0	180.0 0.0	131.9 -103.1	0.0 0.0	180.0 0.0	159.2 75.4	13.6 175.0	No line of sight	No line of sight	35.0	180.0
101:23:52	CSM lose MSFN line of sight	CSM	57.5	-1.2	-114.7	2.1	0.0	180.0	131.9	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight	35.0	180.0
101:25:52	LM lose MSFN line of sight	LM	167.8	-1.2	-127.1	137.0	0.0	180.0	-103.1	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight	90.0	180.0
101:27:03	CSM terminate tracking, inertial attitude hold	CSM LM	57.6 171.2	-1.1 -1.1	-124.3 -130.1	9.1 140.2	0.0 0.0	180.0 0.0	131.5 -103.1	0.0 0.0	180.0 0.0	No line of sight	No line of sight	No line of sight	No line of sight	35.0	180.0
101:28:57	LM enter sunlight	LM	176.2	-1.0	-134.8	144.5	0.0	180.0	-103.1	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight	91.4	180.0
101:34:48	CSM enter sunlight	CSM	57.8	-0.8	-147.9	33.4	0.0	180.0	131.5	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight	47.6	180.0
101:48:18	CSM maneuver to SXT tracking attitude	CSM LM	58.2 188.9	-0.1 -0.2	170.9 178.3	174.9 -168.3	0.0 0.0	180.0 0.0	-127.2 -103.1	0.0 0.0	180.0 0.0	No line of sight	No line of sight	No line of sight	No line of sight	35.0	180.0
101:59:18	LM maneuver to RR tracking attitude	CSM LM	58.3 165.0	0.6 0.3	137.0 151.2	-161.0 60.2	0.0 0.0	180.0 0.0	98.4 98.4	0.0 0.0	180.0 0.0	No line of sight	No line of sight	No line of sight	No line of sight	35.0	180.0
102:08:18	CSM terminate tracking, maneuver to MI insertion burn attitude, inertial attitude hold	CSM LM	58.4 131.8	1.0 0.8	110.0 127.8	-79.5 68.3	0.0 0.0	180.0 0.0	-82.2 83.2	0.0 0.0	180.0 0.0	No line of sight	No line of sight	No line of sight	No line of sight	104.6 90.0	0.0 180.0
102:09:57	CSM acquire MSFN line of sight	CSM	58.3	1.1	103.0	-72.5	0.0	180.0	-82.2	0.0	180.0	55.0	174.1	161.8	-179.1	107.5	0.0
102:14:19	LM acquire MSFN line of sight	LM	105.3	1.0	111.2	72.6	0.0	180.0	71.0	0.0	180.0	98.9	-175.2	8.5	1.8	90.0	180.0
102:19:18	LM terminate tracking, maneuver to descent stage jettison attitude, inertial attitude hold	CSM LM	58.2 82.2	1.2 1.2	76.6 96.8	-46.1 76.1	0.0 0.0	180.0 0.0	-82.2 60.1	0.0 0.0	180.0 0.0	54.5 88.0	174.1 -172.5	161.8 19.5	-179.1 0.8	127.6 90.0	0.0 180.0
102:33:18	Begin descent stage jettison	CSM LM	57.8 26.1	0.9 1.1	33.9 52.9	-3.5 180.0	0.0 0.0	180.0 0.0	-82.2 127.1	0.0 0.0	180.0 0.0	54.8 147.9	174.1 -8.9	161.8 40.7	-179.1 0.4	161.4 176.2	0.0 180.0
102:36:18	Complete descent stage jettison, maneuver to insertion burn attitude, inertial attitude hold	CSM LM	57.7 17.7	0.8 1.1	24.2 42.2	6.2 -170.0	0.0 0.0	180.0 0.0	-82.2 119.6	0.0 0.0	180.0 0.0	54.8 147.0	174.1 8.8	161.8 40.0	-179.1 -0.4	161.4 168.4	0.0 180.0
102:43:18	APS insertion burn ignition	CSM LM	57.6 8.0	0.4 0.7	3.5 19.1	26.8 155.6	0.0 0.0	180.0 0.0	-82.2 62.2	0.0 0.0	180.0 0.0	55.0 89.7	175.0 4.8	161.8 17.4	-0.4 -179.2	171.5 152.9	180.0 0.0

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 2: CSM/LM Undocking to LM APS Burn to Depletion

Mission Time (hr:min:sec)	Event	Vehicle	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth			Look Angles to Sun			Look Angles to Other Vehicle		
			Altitude (n.mi.)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)			
102:43:33	Insertion burn cutoff, inertial attitude hold	CSM	57.5	0.3	2.7	27.6	0.0	180.0	-82.2	0.0	0.0	55.0	174.1	161.8	-179.1	170.8	180.0			
		LM	8.0	0.6	18.2	156.5	0.0	180.0	62.2	0.0	180.0	89.7	4.8	17.4	-179.2	153.7	0.0			
102:46:58	CSM enter lunar umbra	CSM	57.5	0.1	-7.7	166.1	0.0	0.0	-82.2	0.0	0.0	55.0	174.1	No line of sight	No line of sight	169.9	180.0			
102:47:58	LM enter lunar umbra	LM	10.1	0.4	3.5	169.7	0.0	180.0	62.2	0.0	180.0	89.7	4.8	No line of sight	No line of sight	166.0	0.0			
103:01:33	LM maneuver to RR tracking attitude	CSM	57.2	-0.8	-52.1	82.4	0.0	0.0	-82.2	0.0	0.0	55.0	174.1	No line of sight	No line of sight	150.8	180.0			
		LM	21.3	-0.6	-40.8	94.8	0.0	0.0	-58.4	0.0	0.0	31.6	-9.1	No line of sight	No line of sight	90.0	180.0			
103:06:33	CSM maneuver to SXT tracking - VHF ranging attitude	CSM	57.3	-1.0	-67.4	-130.0	0.0	0.0	50.2	0.0	0.0	77.2	-175.1	No line of sight	No line of sight	35.0	180.0			
		LM	26.3	-0.8	-56.8	94.4	0.0	0.0	-74.8	0.0	0.0	48.0	-6.4	No line of sight	No line of sight	90.0	180.0			
103:18:33	CSM terminate tracking, maneuver to MI CSI burn attitude, inertial attitude hold	CSM	57.4	-1.2	-104.0	-133.2	0.0	0.0	10.6	0.0	0.0	37.7	-172.2	No line of sight	No line of sight	35.0	180.0			
		LM	37.2	-1.2	-94.7	92.5	0.0	0.0	-114.4	0.0	0.0	87.6	-4.7	No line of sight	No line of sight	90.0	180.0			
103:22:03	CSM lose MSFN line of sight	CSM	57.5	-1.2	-114.7	-121.0	0.0	0.0	10.6	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	48.0	180.0			
103:24:01	LM lose MSFN line of sight	LM	40.7	-1.2	-111.7	91.7	0.0	0.0	-133.9	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	90.0	180.0			
103:24:33	LM terminate tracking, maneuver to CSI burn attitude, inertial attitude hold	CSM	57.6	-1.2	-122.3	162.0	0.0	180.0	-82.5	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight	38.6	180.0			
		LM	41.0	-1.2	-113.4	-28.4	0.0	0.0	106.1	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	30.1	0.0			
103:33:17	CSM enter sunlight	CSM	57.8	-0.9	-148.9	178.5	0.0	180.0	-82.5	0.0	180.0	No line of sight	No line of sight	162.1	-179.1	9.9	180.0			
103:33:46	CSL burn ignition (RCS plus X-axis 4 jets)	CSM	57.8	-0.8	-150.4	180.0	0.0	180.0	-82.5	0.0	180.0	No line of sight	No line of sight	162.1	-179.1	9.9	180.0			
		LM	43.3	-1.0	-141.8	0.0	0.0	0.0	106.1	0.0	0.0	No line of sight	No line of sight	162.1	-179.1	8.3	180.0			
103:34:18	CSL burn cutoff, inertial attitude hold	CSM	57.9	-0.8	-152.0	-178.4	0.0	180.0	-82.5	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight	0.2	-177.3			
		LM	43.3	-1.0	-143.5	1.6	0.0	0.0	106.0	0.0	0.0	No line of sight	No line of sight	26.4	179.4	6.2	-177.3			
103:36:52	LM enter sunlight	LM	43.3	-0.8	-151.5	7.8	0.0	0.0	106.0	0.0	0.0	No line of sight	No line of sight	136.9	0.4	35.0	180.0			
103:40:18	CSM and LM maneuver to SXT tracking - VHF ranging and RR tracking attitude, respectively	CSM	58.0	-0.5	-170.3	-134.9	0.0	0.0	-57.3	0.0	0.0	No line of sight	No line of sight	98.1	179.7	90.0	180.0			
		LM	43.3	-0.6	-162.2	92.0	0.0	0.0	177.7	0.0	0.0	No line of sight	No line of sight	139.6	179.6	35.0	180.0			
104:08:12	CSM acquire MSFN line of sight	CSM	58.3	1.1	104.8	-133.7	0.0	0.0	-141.0	0.0	0.0	114.0	-5.1	139.6	179.6	35.0	180.0			
104:11:03	LM acquire MSFN line of sight	LM	43.0	1.1	102.0	95.3	0.0	0.0	88.1	0.0	0.0	114.9	-174.8	8.4	178.2	90.0	180.0			
104:20:18	CSM and LM terminate tracking, CSM maneuver to MI CDH burn attitude, inertial attitude hold; LM maneuver to CDH burn attitude, inertial attitude hold	CSM	58.1	1.2	68.0	-124.6	0.0	0.0	-168.3	0.0	0.0	141.2	-172.5	112.0	0.3	43.2	0.0			
		LM	42.9	1.2	73.2	54.5	0.0	0.0	16.1	0.0	0.0	43.1	173.1	63.6	0.2	47.6	180.0			
104:31:42	CDH burn ignition (RCS minus X-axis 4 jets)	CSM	57.8	0.9	33.2	-90.0	0.0	180.0	-168.3	0.0	180.0	141.2	-172.4	112.0	0.3	13.2	0.0			
		LM	42.9	1.0	37.7	90.0	0.0	0.0	16.1	0.0	0.0	43.0	-173.0	63.5	0.3	81.2	180.0			
104:31:45	CDH burn cutoff, inertial attitude hold	CSM	57.8	0.9	33.1	-90.0	0.0	180.0	-168.3	0.0	180.0	141.2	-172.4	112.0	0.3	13.2	0.0			
		LM	42.9	1.0	37.5	90.0	0.0	0.0	16.1	0.0	0.0	43.0	-173.0	63.5	0.3	81.2	180.0			
104:35:45	CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively	CSM	57.7	0.7	20.9	-131.1	0.0	0.0	138.2	0.0	0.0	164.1	-162.5	58.6	179.7	35.0	180.0			
		LM	42.8	0.8	25.1	99.7	0.0	0.0	13.2	0.0	0.0	40.0	-172.7	66.4	0.3	90.0	180.0			
104:45:29	CSM enter lunar umbra	CSM	57.5	0.1	-8.7	-129.2	0.0	0.0	109.8	0.0	0.0	136.0	-173.2	30.2	179.5	35.0	180.0			
104:45:44	LM enter lunar umbra	LM	42.4	0.2	-6.1	102.4	0.0	0.0	-151.1	0.0	0.0	121.4	-157.0	94.8	0.3	90.0	180.0			
104:52:34	CSM and LM terminate tracking, CSM maneuver to MI TPI burn attitude, inertial attitude hold; LM maneuver to TPI burn attitude, inertial attitude hold	CSM	57.3	-0.5	-37.0	-126.4	0.0	0.0	85.2	0.0	0.0	113.3	-174.9	No line of sight	No line of sight	35.0	180.0			
		LM	42.3	-0.4	-34.2	103.7	0.0	0.0	-39.8	0.0	0.0	14.4	-19.2	No line of sight	No line of sight	90.0	180.0			
105:08:57	TPI burn ignition (RCS plus Z-axis 4 jets)	CSM	57.3	-1.2	-80.3	-110.7	0.0	0.0	45.4	0.0	0.0	71.4	-175.0	No line of sight	No line of sight	35.0	180.0			
		LM	42.2	-1.2	-76.7	26.9	0.2	-0.1	-163.0	0.2	-0.1	136.9	-6.5	No line of sight	No line of sight	0.3	-137.4			

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 2: CSM/LM Undocking to LM APS Burn to Depletion

Mission Time (hr:min:sec)	Vehicle	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Look Angles to Other Vehicle	
			Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
105:09:13	CSM	TPI burn cutoff, CSM and LM maneuver to SXT tracking - VHF ranging and RR tracking attitude, respectively	57.3	-1.2	-81.1	-116.5	0.0	0.0	51.2	0.0	0.0	77.1	-175.2	No line of sight	No line of sight	35.0	180.0
	LM		42.4	-1.2	-79.5	116.9	0.0	0.0	-73.8	0.0	0.0	48.1	-6.3	No line of sight	No line of sight	90.0	180.0
105:19:12	LM	LM lose MSFN line of sight	44.2	-1.2	-111.7	127.8	0.0	0.0	-91.0	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	90.0	180.0
105:20:07	CSM	CSM lose MSFN line of sight	57.5	-1.2	-114.3	-101.9	0.0	0.0	29.3	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight	35.0	180.0
105:31:49	CSM	CSM enter sunlight	57.8	-0.9	-150.0	-84.7	0.0	0.0	19.1	0.0	0.0	No line of sight	No line of sight	60.6	0.3	35.0	180.0
105:42:13	LM	LM enter sunlight	49.4	-0.8	-151.4	157.5	0.0	0.0	-107.6	0.0	0.0	No line of sight	No line of sight	172.7	177.9	90.0	180.0
105:50:14	CSM	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 3000 ft	58.3	0.2	153.8	-93.3	0.0	180.0	-50.2	0.0	-179.4	No line of sight	No line of sight	130.0	179.7	0.0	0.0
	LM		57.9	0.2	153.8	30.0	0.4	179.7	73.1	0.4	179.8	No line of sight	No line of sight	6.6	179.1	90.0	180.0
105:50:30	CSM	Braking burn cutoff, CSM and LM continue tracking	58.3	0.2	153.1	-92.5	0.0	180.0	-49.4	0.0	-179.4	No line of sight	No line of sight	129.2	179.7	0.2	0.0
	LM		57.9	0.2	153.1	30.8	0.4	177.8	73.9	0.4	179.2	No line of sight	No line of sight	7.4	-179.2	90.0	180.0
105:51:27	CSM	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 1500 ft	58.3	0.3	150.2	-53.5	0.3	-179.6	-14.1	0.3	-179.6	No line of sight	No line of sight	94.0	179.8	0.2	0.0
	LM		58.1	0.3	150.2	33.2	0.3	179.7	73.9	0.4	179.7	No line of sight	No line of sight	5.8	179.2	90.0	180.0
105:51:39	CSM	Braking burn cutoff, CSM and LM continue tracking	58.3	0.3	149.6	-52.9	0.3	-179.6	-14.1	0.3	-179.6	No line of sight	No line of sight	93.9	179.8	0.2	0.0
	LM		58.1	0.3	149.6	34.0	0.3	179.7	74.8	0.4	179.7	No line of sight	No line of sight	6.7	179.2	90.0	180.0
105:53:04	CSM	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 500 ft	58.3	0.4	145.2	-48.4	0.3	-179.6	-13.9	0.3	-179.6	No line of sight	No line of sight	93.6	179.9	0.4	0.0
	LM		58.3	0.4	145.2	42.6	0.3	179.7	75.9	0.3	179.7	No line of sight	No line of sight	6.1	179.5	90.0	180.0
105:53:10	CSM	Braking burn cutoff, CSM and LM continue tracking	58.3	0.4	144.9	-48.0	0.3	-179.6	-13.9	0.3	-179.6	No line of sight	No line of sight	93.6	179.9	0.4	0.0
	LM		58.3	0.4	144.9	42.1	0.3	179.7	75.4	0.3	179.6	No line of sight	No line of sight	5.7	179.5	90.0	180.0
105:54:24	CSM	LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 100 ft	58.3	0.5	141.2	-43.9	0.3	-179.7	-13.5	0.3	-179.6	No line of sight	No line of sight	93.2	180.0	0.6	0.0
	LM		58.3	0.5	141.2	46.2	0.3	179.7	76.6	0.3	179.6	No line of sight	No line of sight	3.1	179.6	90.0	180.0
105:54:30	CSM	Braking burn cutoff, CSM-LM range = 85 ft, CSM-LM range	58.3	0.5	140.9	-43.6	0.3	-179.7	-13.5	0.3	-179.6	No line of sight	No line of sight	93.2	180.0	0.7	0.0
	LM		58.3	0.5	140.9	46.6	0.3	179.7	76.7	0.3	179.6	No line of sight	No line of sight	3.0	179.7	90.0	180.0
105:57:10	CSM	CSM and LM maneuver to docking attitude, CSM-LM range = 50 ft	58.4	0.7	128.0	-20.8	0.3	120.0	-14.5	0.3	120.0	No line of sight	No line of sight	94.2	-120.0	0.0	0.0
	LM		58.4	0.7	128.0	148.2	-0.3	180.0	165.5	-0.3	180.0	No line of sight	No line of sight	85.8	0.0	0.0	0.0
106:06:33	CSM	Acquire MSFN line of sight	58.3	1.1	104.2	-1.1	0.3	120.0	-14.5	0.3	120.0	12.0	-45.7	94.2	-120.0	0.0	0.0
	LM		58.3	1.1	104.2	148.2	-0.3	180.0	165.5	-0.3	180.0	168.0	-75.3	85.8	0.0	0.0	0.0
106:20:00	CSM	CSM/LM docking, inertial attitude hold	58.1	1.2	64.0	-10.0	0.3	120.0	-14.5	0.3	120.0	12.0	-45.7	94.2	-120.0	0.0	0.0
	LM		58.1	1.2	64.0	-140.0	-0.3	180.0	165.5	-0.3	180.0	168.0	-75.3	85.8	0.0	0.0	0.0
106:43:56	CSM	Enter lunar umbra	57.5	0.1	-9.7	109.9	0.3	120.0	-14.5	0.3	120.0	12.0	-45.7	No line of sight	No line of sight		
106:50:45	CSM	Maneuver to LM jettison attitude, inertial attitude hold	57.4	-0.2	-30.0	-150.0	0.0	-60.0	70.3	0.0	-60.0	95.1	-115.4	No line of sight	No line of sight		
107:18:21	CSM	Lose MSFN line of sight	57.5	-1.2	-114.6	15.4	0.0	-60.0	70.3	0.0	-60.0	No line of sight	No line of sight	No line of sight	No line of sight		
107:30:17	CSM	Enter sunlight	57.8	-0.8	-151.2	-28.9	0.8	-60.0	70.3	0.0	-60.0	No line of sight	No line of sight	No line of sight	No line of sight		
108:04:34	CSM	Acquire MSFN line of sight	58.3	1.1	104.3	75.7	0.8	-60.0	70.3	0.0	-60.0	95.1	-115.4	No line of sight	No line of sight		
108:09:24	CSM	Complete LM jettison, start CSM evasive maneuver	58.3	1.2	90.0	89.9	0.0	-60.0	70.3	0.0	-60.0	95.2	-115.4	9.5	61.5	0.0	0.0
	LM		58.3	1.2	90.0	-90.0	0.0	-109.6	0.0	0.0	0.0	84.7	-4.6	170.6	178.3	0.0	0.0
108:09:29	CSM	CSM complete evasive maneuver, maneuver to LM observation attitude, inertial attitude hold	58.3	1.2	89.7	-75.0	0.0	180.0	-94.8	0.0	180.0	70.0	175.1	174.6	-177.1	15.2	0.0
	LM		58.3	1.2	89.7	-89.7	0.0	0.0	-109.6	0.0	0.0	84.7	-4.6	170.6	178.3	179.5	0.0
108:38:57	CSM	LM unmanned APS burn to depletion ignition	57.9	0.4	0.0	14.4	0.0	180.0	-94.8	0.0	180.0	70.5	175.1	174.7	-177.1	41.2	0.0
	LM		57.6	0.4	0.0	0.0	0.0	-109.6	0.0	0.0	0.0	85.2	-4.6	170.6	178.3	153.5	0.0
108:42:30	CSM	CSM and LM enter umbra	57.8	0.1	-10.8	25.3	0.0	180.0	-94.8	0.0	180.0	70.6	175.2	174.7	-177.1	15.1	0.0
	LM		71.1	0.0	-14.4	14.1	0.0	0.0	-109.6	0.0	0.0	85.2	-4.6	170.6	178.3	171.6	0.0

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit
Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun	
		Altitude (m)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	NIGA (deg)	OCA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
108:42:31	1 M unmaned APS burn to depletion cut off	57.8	0.1	-10.8	25.3	0.0	180.0	-94.8	0.0	180.0	70.6	175.2	No line of sight	No line of sight
109:00:00	Maneuver to sleep attitude, inertial attitude hold	57.4	-0.3	-74.1	23.5	0.0	155.0	-149.7	0.0	135.0	125.6	-140.5	No line of sight	No line of sight
109:16:43	Lose MSFN line of sight	57.3	-1.2	-115.0	71.2	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	No line of sight	No line of sight
109:24:50	Enter sunlight	57.5	-0.3	-152.0	111.1	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	130.4	44.6
110:02:53	Acquire MSFN line of sight	58.2	1.0	104.2	-140.4	0.0	155.0	-149.7	0.0	135.0	125.6	-110.5	No line of sight	No line of sight
110:40:59	Enter lunar umbra	57.8	0.1	-11.5	-15.9	0.0	155.0	-149.7	0.0	135.0	126.2	-140.6	No line of sight	No line of sight
111:14:55	Lose MSFN line of sight	57.3	-1.2	-115.2	71.5	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	No line of sight	No line of sight
111:27:19	Enter sunlight	57.5	-0.3	-153.1	111.1	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	130.3	44.6
112:01:11	Acquire MSFN line of sight	58.2	1.0	103.4	-140.1	0.0	155.0	-149.7	0.0	135.0	126.6	-140.5	No line of sight	No line of sight
112:39:10	Enter lunar umbra	57.4	0.2	-12.9	-23.7	0.0	155.0	-149.7	0.0	135.0	127.2	-140.6	No line of sight	No line of sight
113:13:10	Lose MSFN line of sight	57.3	-1.2	-115.4	72.5	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	No line of sight	No line of sight
113:25:50	Enter sunlight	57.5	-0.8	-154.1	111.1	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	130.3	44.6
113:59:40	Acquire MSFN line of sight	58.2	1.0	103.4	-141.7	0.0	155.0	-149.7	0.0	135.0	127.6	-140.5	No line of sight	No line of sight
114:37:59	Enter lunar umbra	57.8	0.1	-13.8	-29.9	0.0	155.0	-149.7	0.0	135.0	128.2	-140.6	No line of sight	No line of sight
115:11:26	Lose MSFN line of sight	57.3	-1.2	-115.6	71.6	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	No line of sight	No line of sight
115:24:40	Enter sunlight	57.5	-0.8	-155.1	111.1	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	130.2	44.6
115:57:11	Acquire MSFN line of sight	58.2	1.0	104.9	-149.3	0.0	155.0	-149.7	0.0	135.0	128.6	-140.3	No line of sight	No line of sight
116:36:29	Enter lunar umbra	57.8	0.1	-13.8	-30.1	0.0	155.0	-149.7	0.0	135.0	129.2	-140.5	No line of sight	No line of sight
117:09:02	Lose MSFN line of sight	57.3	-1.2	-114.2	79.1	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	No line of sight	No line of sight
117:22:50	Enter sunlight	57.5	-0.3	-153.1	110.9	0.0	155.0	-149.7	0.0	135.0	No line of sight	No line of sight	130.1	44.6
117:55:25	Acquire MSFN line of sight	58.2	1.0	104.6	-140.9	0.0	155.0	-149.7	0.0	135.0	129.6	-140.5	No line of sight	No line of sight
118:00:00	Maneuver to initial attitude for oblique photographs of L&P, local attitude hold	58.3	1.1	96.7	-8.0	0.0	180.0	-21.4	0.0	150.0	4.5	159.4	31.1	-179.7
118:19:29	Start 0.5 degree/sec pitch rate for photography of L&P	58.2	1.0	31.4	-25.9	0.0	150.0	-80.4	0.0	150.0	-1.1	175.2	106.8	-179.2
118:22:04	Terminate pitch rate, inertial attitude hold	58.1	0.9	23.5	-77.7	0.0	150.0	-158.1	0.0	150.0	138.2	170.4	121.7	-0.3
118:34:59	Enter lunar umbra	57.3	-1.2	-115.6	-15.3	0.0	150.0	-149.7	0.0	150.0	14.4	175.2	No line of sight	No line of sight
118:55:00	Begin IMU realignment	57.4	-1.1	-60.3	31.7	0.0	150.0	-150.1	0.0	150.0	135.9	175.2	No line of sight	No line of sight
119:07:21	Lose MSFN line of sight	57.3	-1.2	-114.4	59.4	0.0	150.0	-150.1	0.0	150.0	No line of sight	No line of sight	No line of sight	No line of sight
119:16:00	Maneuver to strip photography attitude, local attitude hold	57.3	-1.2	-122.7	-78.0	0.0	150.0	55.4	0.0	150.0	No line of sight	No line of sight	No line of sight	No line of sight
119:21:19	Enter sunlight	57.5	-0.3	-153.1	-78.0	0.0	150.0	-77.0	0.0	150.0	No line of sight	No line of sight	39.8	-179.7
119:53:43	Acquire MSFN line of sight	58.2	1.0	104.2	-78.0	0.0	150.0	-77.0	0.0	150.0	57.9	125.1	157.3	-179.1
119:55:00	Maneuver at subsolar point to turn windows away from sun, continue strip photography, local attitude hold	58.2	1.0	100.4	-102.0	0.0	0.0	-104.4	0.0	0.0	85.8	-1.1	175.0	176.9

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Look Angles to Landmark	
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Shaft (deg)	Trunnion (deg)
120:06:00	Yaw 20 deg to include L51, local attitude hold	58.3	1.2	66.9	-102.0	20.0	0.0	-138.1	20.0	0.0	118.8	6.5	137.3	156.3		
120:17:00	Yaw -20 deg, adjust attitude, continue strip photography, local attitude hold	58.2	1.0	33.4	-102.0	0.0	0.0	-171.5	0.0	0.0	152.5	-9.0	108.2	179.7		
120:27:00	Terminate strip photography, maneuver to IMU realignment attitude, inertia, attitude hold	58.0	0.5	2.9	-164.3	0.0	0.0	95.3	0.0	0.0	113.7	174.9	15.0	179.4		
120:33:29	Enter lunar umbra	57.8	0.1	-16.8	-144.6	0.0	0.0	95.3	0.0	0.0	113.6	-175.9	No line of sight	No line of sight		
120:35:00	Begin IMU realignment	57.8	-0.2	-21.5	-140.5	0.0	0.0	95.3	0.0	0.0	113.6	-174.9	No line of sight	No line of sight		
121:05:40	Lose MSFN line of sight	57.3	-1.2	-114.9	-47.1	0.0	0.0	95.3	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
121:14:00	Start local attitude hold for landmark tracking	57.4	-1.1	-140.3	-22.0	0.0	0.0	95.3	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
121:19:49	Enter sunlight	57.5	-0.9	-158.1	-22.0	0.0	0.0	77.5	0.0	0.0	No line of sight	-175.7	3.3	4.8		
121:28:51	Begin landmark tracking on CP ₁	57.7	-0.4	-171.5	-22.0	0.0	0.0	50.2	0.0	0.0	No line of sight	-175.7	30.2	0.5	18.3	39.8
121:42:50	Begin landmark tracking on CP ₂	58.0	0.5	131.8	-22.0	0.0	0.0	7.7	0.0	0.0	No line of sight	-175.7	72.6	0.3	6.2	39.2
121:52:03	Acquire MSFN line of sight	58.2	1.0	103.7	-22.0	0.0	0.0	-20.1	0.0	0.0	8.7	-27.9	106.0	0.3		
121:56:06	Begin landmark tracking on F-1	58.3	1.1	91.5	-22.0	0.0	0.0	-34.0	0.0	0.0	16.6	-15.2	114.3	0.3	6.0	39.6
122:16:51	Begin landmark tracking on L10	58.2	1.0	28.2	-22.0	0.0	0.0	-95.4	0.0	0.0	77.9	-4.2	175.9	3.8	5.4	40.0
122:19:51	Maneuver to IMU realignment attitude, inertial attitude hold	58.1	0.8	19.1	175.0	0.0	0.0	92.4	0.0	0.0	109.9	-175.7	12.0	178.7		
122:31:59	Enter lunar umbra	57.8	0.1	-17.4	-148.2	0.0	0.0	92.4	0.0	0.0	109.6	-175.7	No line of sight	No line of sight		
122:35:00	Begin IMU realignment	57.7	0.0	-26.9	-139.0	0.0	0.0	92.4	0.0	0.0	109.6	-175.7	No line of sight	No line of sight		
123:03:56	Lose MSFN line of sight	57.3	-1.2	-115.3	-51.0	0.0	0.0	92.4	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
123:13:22	Start local attitude hold for landmark tracking	57.4	-1.1	-143.0	-22.0	0.0	0.0	92.4	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
123:18:19	Enter sunlight	57.5	-0.9	-159.1	-22.0	0.0	0.0	77.5	0.0	0.0	No line of sight	-175.7	1.8	8.9		
123:27:00	Begin landmark tracking on CP ₁	57.7	-0.4	174.5	-22.0	0.0	0.0	51.3	0.0	0.0	No line of sight	-175.7	29.1	0.6	18.4	40.1
123:41:00	Begin landmark tracking on CP ₂	58.0	0.5	131.8	-22.0	0.0	0.0	8.8	0.0	0.0	No line of sight	-175.7	71.6	0.3	6.5	39.2
123:49:57	Acquire MSFN line of sight	58.2	1.0	104.6	-22.0	0.0	0.0	-18.5	0.0	0.0	4.3	-68.8	99.0	0.3		
123:54:17	Begin landmark tracking on F-1	58.3	1.1	91.5	-22.0	0.0	0.0	-30.7	0.0	0.0	14.3	-16.4	111.1	0.3	6.2	39.6
124:15:02	Begin landmark tracking on L10	58.2	1.0	28.2	-22.0	0.0	0.0	-94.5	0.0	0.0	77.8	-4.1	174.9	3.1	5.3	40.0
124:18:02	Maneuver to IMU realignment attitude, inertial attitude hold	58.1	0.8	19.1	175.0	0.0	0.0	93.4	0.0	0.0	110.0	-175.8	12.9	178.8		
124:30:28	Enter lunar umbra	57.8	0.1	-18.8	-147.1	0.0	0.0	93.4	0.0	0.0	109.7	-175.8	No line of sight	No line of sight		
124:33:00	Begin IMU realignment	57.8	0.0	-26.9	-139.5	0.0	0.0	93.4	0.0	0.0	109.6	-175.8	No line of sight	No line of sight		
125:02:12	Lose MSFN line of sight	57.3	-1.2	-115.3	-50.7	0.0	0.0	93.4	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
125:11:33	Start local attitude hold for landmark tracking	57.4	-1.1	-144.0	-22.0	0.0	0.0	93.4	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
125:16:49	Enter sunlight	57.5	-0.9	-160.1	-22.0	0.0	0.0	77.7	0.0	0.0	No line of sight	-175.8	2.8	3.2		
125:25:10	Begin landmark tracking on CP ₁	57.7	-0.4	174.5	-22.0	0.0	0.0	52.4	0.0	0.0	No line of sight	-175.8	28.1	0.6	18.7	40.2
125:39:10	Begin landmark tracking on CP ₂	58.4	0.5	131.8	-22.0	0.0	0.0	9.9	0.0	0.0	No line of sight	-175.8	70.6	0.3	6.8	39.3

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Look Angles to Landmark	
		Altitude (n.mi.)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Chi (deg)	Theta (deg)	Chi (deg)
125:48:14	Acquire MSFN line of sight	58.2	0.9	104.2	-22.0	0.0	0.0	-17.5	0.0	0.0	4.2	-69.5	98.0	0.3		
125:52:27	Begin landmark tracking on F-1	58.3	1.1	91.5	-22.0	0.0	0.0	-29.6	0.0	0.0	14.2	-16.2	110.1	0.3	6.2	39.6
125:13:12	Begin landmark tracking on F30	58.2	1.0	28.5	-22.0	0.0	0.0	-93.4	0.0	0.0	77.8	-4.0	173.9	2.6	5.0	39.7
126:14:12	Maneuver to IMU realignment attitude, inertial attitude hold	58.2	0.9	19.1	175.0	0.0	0.0	94.5	0.0	0.0	110.0	-175.8	13.9	178.9		
126:28:59	Enter lunar umbra	57.8	0.1	-19.8	-146.3	0.0	0.0	94.5	0.0	0.0	109.7	-175.9	No line of sight	No line of sight		
126:30:00	Begin IMU realignment	57.8	0.0	-22.9	-143.1	0.0	0.0	94.5	0.0	0.0	109.7	-175.9	No line of sight	No line of sight		
127:00:27	Loose MSFN line of sight	57.3	-1.2	-115.7	-51.3	0.0	0.0	94.5	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
127:09:43	Start local attitude hold for landmark tracking	57.4	-1.1	-144.0	-22.0	0.0	0.0	94.5	0.0	0.0	No line of sight	No line of sight	No line of sight	No line of sight		
127:15:19	Enter sunlight	57.5	-0.9	-161.1	-22.0	0.0	0.0	77.6	0.0	0.0	No line of sight	No line of sight	4.8	3.3		
127:23:21	Begin landmark tracking on CP ₁	57.7	-0.4	174.5	-22.0	0.0	0.0	53.4	0.0	0.0	No line of sight	No line of sight	27.2	0.6	19.2	40.0
127:37:20	Begin landmark tracking on CP ₂	58.0	0.5	131.8	-22.0	0.0	0.0	10.9	0.0	0.0	No line of sight	No line of sight	69.6	0.3	7.1	39.3
127:46:32	Acquire MSFN line of sight	58.2	0.9	104.8	-22.0	0.0	0.0	-16.4	0.0	0.0	4.1	-70.2	97.0	0.3		
127:50:37	Begin landmark tracking on F-1	58.3	1.1	91.5	-22.0	0.0	0.0	-28.5	0.0	0.0	14.1	-15.9	109.1	0.3	6.2	39.6
128:11:22	Begin landmark tracking on F30	58.2	1.0	28.2	-22.0	0.0	0.0	-92.2	0.0	0.0	77.6	-3.9	172.8	2.2	5.0	39.7
128:14:20	Maneuver to rest attitude, inertial attitude hold	58.2	0.9	19.2	-55.0	0.0	180.0	-134.3	0.0	180.0	119.7	175.6	145.0	-0.5		
128:27:25	Enter lunar umbra	57.8	0.1	-20.8	-15.5	0.0	180.0	-134.3	0.0	180.0	120.0	175.6	No line of sight	No line of sight		
128:55:27	Loose MSFN line of sight	57.3	-1.2	-115.2	76.6	0.0	180.0	-134.3	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight		
129:13:42	Enter sunlight	57.5	-0.9	-162.1	125.5	0.0	180.0	-134.3	0.0	180.0	No line of sight	No line of sight	145.0	-0.5		
129:44:51	Acquire MSFN line of sight	58.2	0.9	103.4	-146.1	0.0	180.0	-134.3	0.0	180.0	120.3	175.7	145.0	-0.5		
130:25:55	Enter lunar umbra	57.9	0.1	-21.8	-15.2	0.0	180.0	-134.3	0.0	180.0	121.0	175.6	No line of sight	No line of sight		
130:50:44	Loose MSFN line of sight	57.3	-1.2	-115.7	76.6	0.0	180.0	-134.3	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight		
131:10:15	Enter sunlight	57.5	-0.9	-163.1	125.7	0.0	180.0	-134.3	0.0	180.0	No line of sight	No line of sight	144.9	-0.5		
131:42:54	Acquire MSFN line of sight	58.2	0.9	103.4	-146.1	0.0	180.0	-134.3	0.0	180.0	121.3	175.7	144.9	-0.5		
131:55:00	End rest period, maneuver to initial attitude for oblique photography of US3	58.3	1.2	96.3	-89.0	0.0	180.0	-17.1	0.0	180.0	25.0	171.3	118.4	-179.7		
132:14:40	Start 5 min. rest period rate for photography of US3	58.3	0.7	6.4	-8	0.0	180.0	-96.0	0.0	180.0	88.5	174.3	178.7	-167.5		
132:17:20	Terminate rest period, inertial attitude hold	58.0	0.7	-1.5	-77.7	0.0	180.0	-175.5	0.0	180.0	162.4	177.7	103.8	-9.3		
132:24:20	Maneuver to IMU realignment attitude, inertial attitude hold	58.0	0.4	-16.0	-50.0	0.0	180.0	-156.9	0.0	180.0	144.4	173.7	122.3	-0.3		
132:34:24	Enter lunar umbra	57.5	0.1	-22.9	-15.2	0.0	180.0	-156.9	0.0	180.0	144.4	173.7	No line of sight	No line of sight		
132:35:30	Begin IMU realignment	57.5	-0.4	-24.7	-21.1	0.0	180.0	-156.9	0.0	180.0	144.6	173.7	No line of sight	No line of sight		
132:55:01	Loose MSFN line of sight	57.3	-1.2	-116.0	53.1	0.0	180.0	-156.9	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight		
133:00:00	Maneuver to attitude for photo targets of opportunity, local attitude hold	57.3	-1.2	-131.1	-45.0	0.0	180.0	87.9	0.0	180.0	No line of sight	No line of sight	No line of sight	No line of sight		

Table II. Spacecraft Attitude and Trajectory Data
(c) Lunar Orbit (Continued)
Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

Mission Time (hr:min:sec)	Event	Selenographic Position			Local Horizontal			IMU			Look Angles to Earth		Look Angles to Sun		Look Angles to Landmark	
		Altitude (n mi)	Latitude (deg)	Longitude (deg)	Pitch (deg)	Yaw (deg)	Roll (deg)	IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Shaft (deg)	Trunnion (deg)
133:10:49	Enter sunlight	57.5	-0.9	-164.1	-45.0	0.0	180.0	55.1	0.0	180.0	No line of sight		29.4	-179.4		
133:41:11	Acquire MSFN line of sight	58.2	0.9	103.3	-45.0	0.0	180.0	-37.3	0.0	180.0	25.5	171.4	118.0	-179.7		
133:50:00	Maneuver to landmark sighting attitude, local attitude hold	58.3	1.1	76.5	-22.0	0.0	0.0	-40.9	0.0	0.0	29.2	-5.1	121.7	0.4		
134:02:15	Begin landmark tracking on B1	58.3	1.2	39.2	-22.0	0.0	0.0	-76.1	0.0	0.0	0.0		159.0	0.8	22.5	39.5
134:14:08	Begin landmark tracking on 150	58.1	0.7	3.1	-22.0	0.0	0.0	-114.2	0.0	0.0	102.7	-3.7	165.0	178.9	-4.7	39.5
134:17:08	Roll 180 deg for communications, inertial attitude hold	58.0	0.5	-6.1	-22.0	0.0	180.0	-123.3	0.0	180.0	111.8	176.2	155.9	-0.7		
134:22:57	Enter lunar umbra	57.8	0.1	-23.8	-4.4	0.0	180.0	-123.3	0.0	180.0	111.9	176.2	No line of sight			
134:53:13	Lose MSFN line of sight	57.3	-1.2	-116.1	87.6	0.0	180.0	-123.3	0.0	180.0	No line of sight		No line of sight			
135:09:18	Enter sunlight	57.5	-0.9	-165.1	136.5	0.0	180.0	-123.3	0.0	180.0	No line of sight		155.8	-0.7		
135:30:00	Maneuver to strip photography attitude, local attitude hold	58.0	0.4	131.8	-102.0	0.0	0.0	-64.7	0.0	0.0	No line of sight		145.6	0.5		
135:39:29	Acquisition of MSFN line of sight	58.2	0.9	103.0	-102.0	0.0	0.0	-93.5	0.0	0.0	82.6	-3.5	174.4	2.3		
135:45:23	Yaw -20 deg to include highland site, local attitude hold	58.3	1.1	85.0	-102.0	-20.0	0.0	-111.4	-20.0	0.0	98.6	-6.9	156.9	-122.9		
136:03:30	Yaw 20 deg, adjust attitude, continue strip photography, local attitude hold	58.2	1.1	29.9	-102.0	0.0	0.0	-156.4	0.0	0.0	155.5	-8.4	112.7	179.7		
136:20:00	Maneuver to TEI attitude, rolled 180 deg, inertial attitude hold	58.0	0.2	-20.4	166.9	-0.2	0.0	52.4	-0.2	0.0	62.8	-176.1	28.5	1.0		
136:21:28	Enter lunar umbra	57.9	0.1	-24.8	171.3	-0.2	0.0	52.4	-0.2	0.0	62.7	-176.1	No line of sight			
136:35:00	Begin IMU realignment	57.5	-0.7	-66.1	-147.5	-0.2	0.0	52.4	-0.2	0.0	62.6	-176.1	No line of sight			
136:45:00	Roll 180 deg to TEI burn attitude, inertial attitude hold	57.4	-1.1	-96.6	-117.1	-0.2	180.0	52.4	-0.2	180.0	62.3	3.9	No line of sight			
136:51:28	Lose MSFN line of sight	57.3	-1.2	-116.2	-97.5	-0.2	180.0	52.4	-0.2	180.0	No line of sight		No line of sight			
137:07:48	Enter sunlight	57.5	-0.9	-166.1	-47.8	-0.2	180.0	52.4	-0.2	180.0	No line of sight		28.6	-179.0		
137:20:22	TEI burn ignition	58.8	-0.1	155.6	-9.6	-0.2	180.0	52.4	-0.2	180.0	No line of sight		28.6	-179.0		

Table II. Spacecraft Attitude and Trajectory Data
(d) Transearth

Mission Time (hr:min:sec)	Event	IMU Gimbal Angles			Look Angles to Earth		Look Angles to Moon		Look Angles to Sun	
		IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
137:23:11	TEI cutoff, maneuver to lunar surface observation attitude, inertial attitude hold	-39.2	-0.4	-179.7	No line of sight		0.0	0.0	120.2	-179.4
137:29:15	Acquire MSFN									
138:00:00	Begin IMU realignment, change to PTC REFSMMAT	-39.2	-0.4	-179.7	29.4	173.2	29.3	0.0	120.2	-179.4
138:30:00	Begin PTC	-90.0	0.0	40.8	87.8	-132.6	89.7	-6.7	90.0	136.2
150:30:00	Terminate PTC, begin IMU realignment				Maneuver spacecraft as required					
151:00:00	Begin star-lunar landmark navigation sightings				Maneuver spacecraft as required					
152:20:00	Midcourse correction				Maneuver spacecraft as required					
152:45:00	Begin PTC	-90.0	0.0	130.9	87.9	136.0	89.3	-76.6	90.0	45.6
165:00:00	Terminate PTC, begin IMU realignment				Maneuver spacecraft as required					
165:20:00	Begin star-earth horizon navigation sightings				Maneuver spacecraft as required					
165:45:00	Begin PTC at 3 revolutions per hour roll rate without attitude control	-90.0	0.0	130.9	88.0	133.6	89.4	-74.6	90.0	45.0
169:45:00	Terminate PTC test, resume normal PTC	-90.0	0.0	130.9	88.1	132.5	89.4	-74.2	90.0	44.8
171:00:00	Terminate PTC, begin star-earth horizon navigation sightings				Maneuver spacecraft as required					
171:30:00	Begin PTC	-90.0	0.0	40.9	88.1	-138.1	89.5	16.0	90.0	134.8
174:30:00	Terminate PTC, begin star-earth horizon navigation sightings				Maneuver spacecraft as required					
175:30:00	Begin IMU realignment				Maneuver spacecraft as required					
176:50:00	Midcourse correction				Maneuver spacecraft as required					

Table II. Spacecraft Attitude and Trajectory Data
(d) Transearth (Continued)

Mission Time (hr:min:sec)	Event	IMU Gimbal Angles			Look Angles to Earth		Look Angles to Moon		Look Angles to Sun	
		IGA (deg)	MGA (deg)	OGA (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)	Theta (deg)	Phi (deg)
177:15:00	Begin PTC	-90.0	0.0	-49.1	88.3	-50.6	89.5	107.0	90.0	-135.5
187:30:00	Terminate PTC, begin IMU realignment, change to entry REFSMAT	Maneuver spacecraft as required								
188:50:00	Midcourse correction	Maneuver spacecraft as required								
189:50:00	Maneuver to entry attitude, inertial attitude hold	156.0	0.0	0.0	125.8	180.0	59.1	0.6	172.4	28.2
190:15:00	Begin IMU realignment	Maneuver spacecraft as required								
191:33:00	CM/SM separation	-92.7	-45.0	0.0	74.8	19.2	64.8	151.0	73.2	23.1
191:50:32	Entry interface	156.0	0.0	0.0	114.0	0.0	58.3	0.5	172.3	27.9

Table III. F Mission IMU Matrices; Launch Date May 18, 1969;
72-Degree Launch Azimuth

Launch Pad

$$\begin{array}{c} X \\ Y \\ Z \end{array} \begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} = \begin{array}{ccc} X & Y & Z \\ \begin{bmatrix} -0.80333901 \\ 0.53013973 \\ 0.27128991 \end{bmatrix} & \begin{bmatrix} 0.07758623 \\ 0.54483762 \\ -0.83494449 \end{bmatrix} & \begin{bmatrix} -0.59044622 \\ -0.64969514 \\ -0.4788209 \end{bmatrix} \end{array}$$

PTC

$$\begin{array}{c} X \\ Y \\ Z \end{array} \begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} = \begin{array}{ccc} X & Y & Z \\ \begin{bmatrix} -0.5 \\ -0.79453912 \\ -0.34453959 \end{bmatrix} & \begin{bmatrix} -0.8660254 \\ 0.45872741 \\ 0.19892003 \end{bmatrix} & \begin{bmatrix} 0.0 \\ 0.39784005 \\ -0.91745479 \end{bmatrix} \end{array}$$

Landing Site

$$\begin{array}{c} X \\ Y \\ Z \end{array} \begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} = \begin{array}{ccc} X & Y & Z \\ \begin{bmatrix} 0.95054742 \\ -0.29246011 \\ -0.10453089 \end{bmatrix} & \begin{bmatrix} 0.01675490 \\ -0.38436486 \\ 0.92302923 \end{bmatrix} & \begin{bmatrix} -0.31012723 \\ -0.87563163 \\ -0.37025716 \end{bmatrix} \end{array}$$

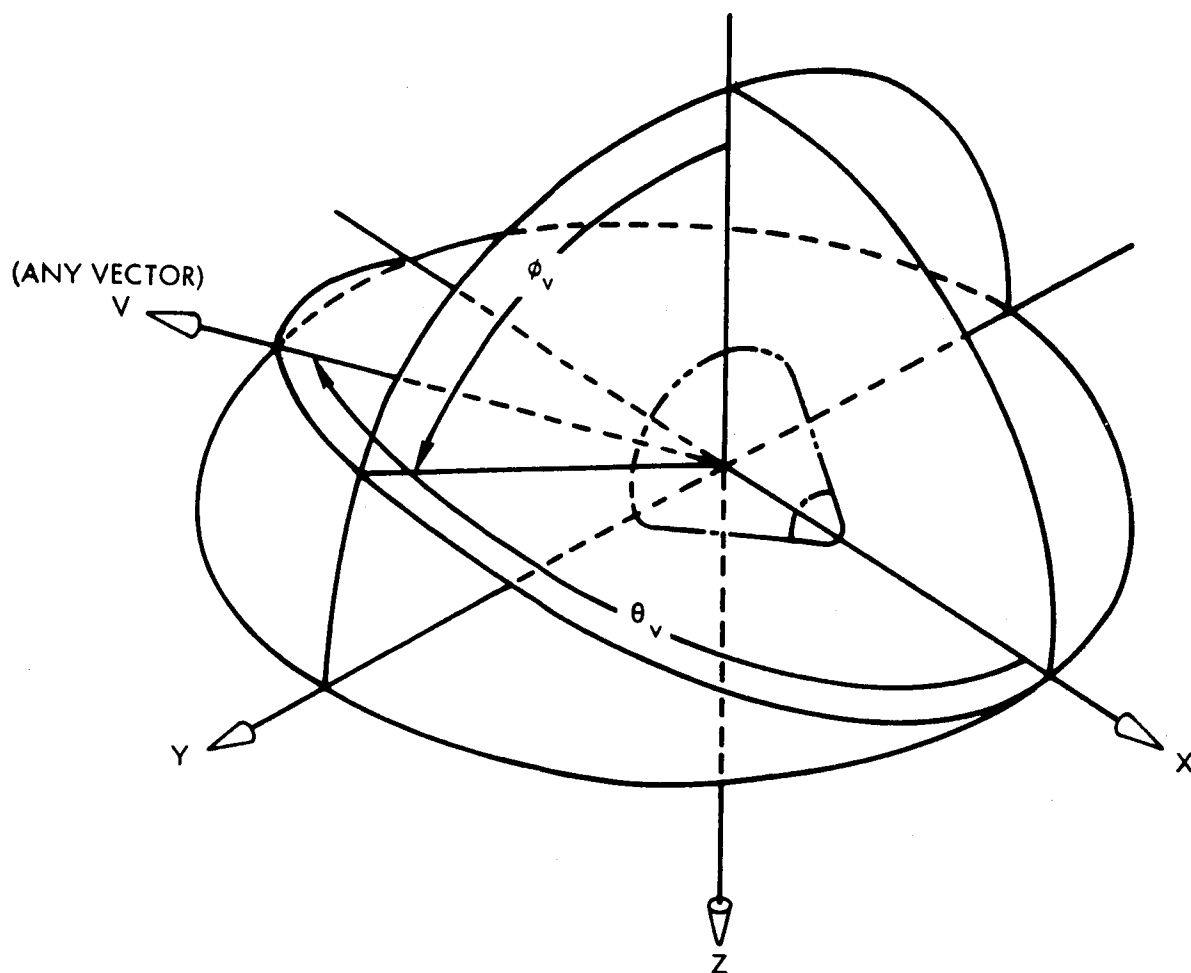
Entry

$$\begin{array}{c} X \\ Y \\ Z \end{array} \begin{bmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{bmatrix} = \begin{array}{ccc} X & Y & Z \\ \begin{bmatrix} 0.82559319 \\ 0.50208567 \\ 0.25749931 \end{bmatrix} & \begin{bmatrix} -0.00450212 \\ 0.46219075 \\ -0.88676912 \end{bmatrix} & \begin{bmatrix} -0.56424786 \\ 0.73095123 \\ 0.38384198 \end{bmatrix} \end{array}$$

Table IV. Prime Landmark Tracking Targets for May 18, 1969 Launch

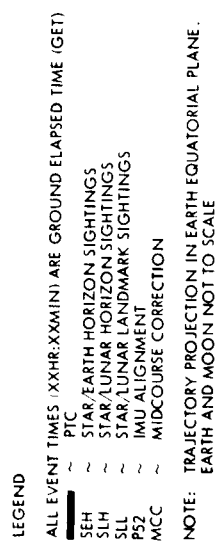
<u>Landmark Nomenclature</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Altitude (n mi)</u>
IP for CP1	0.000	178.438E	0.00
CP1	0.875N	170.146E	0.00
IP for CP2	0.800N	132.480E	0.00
CP2	1.000N	127.400E	0.00
IP for F-1	1.280N	93.840E	0.00
F-1	1.600N	86.880E	0.00
IP for B1	1.505N	40.105E	-0.97
B1 (LS1 landmark)	2.522N	35.036E	-1.49
IP for 130	1.885N	28.726E	-1.03
130 (LS2 landmark)	1.266N	23.679E	-1.68
IP for 150	0.300N	3.383E	0.30
150 (LS3 landmark)	0.283N	1.429W	-1.00





ϕ_v MEASURED FROM MINUS Z-BODY AXIS POSITIVELY ABOUT
X-BODY AXIS TO VECTOR PROJECTION IN Y-Z PLANE
 θ_v SMALLEST ANGLE FROM X-BODY AXIS TO VECTOR

Figure 1. Spacecraft Body Aspect Angles



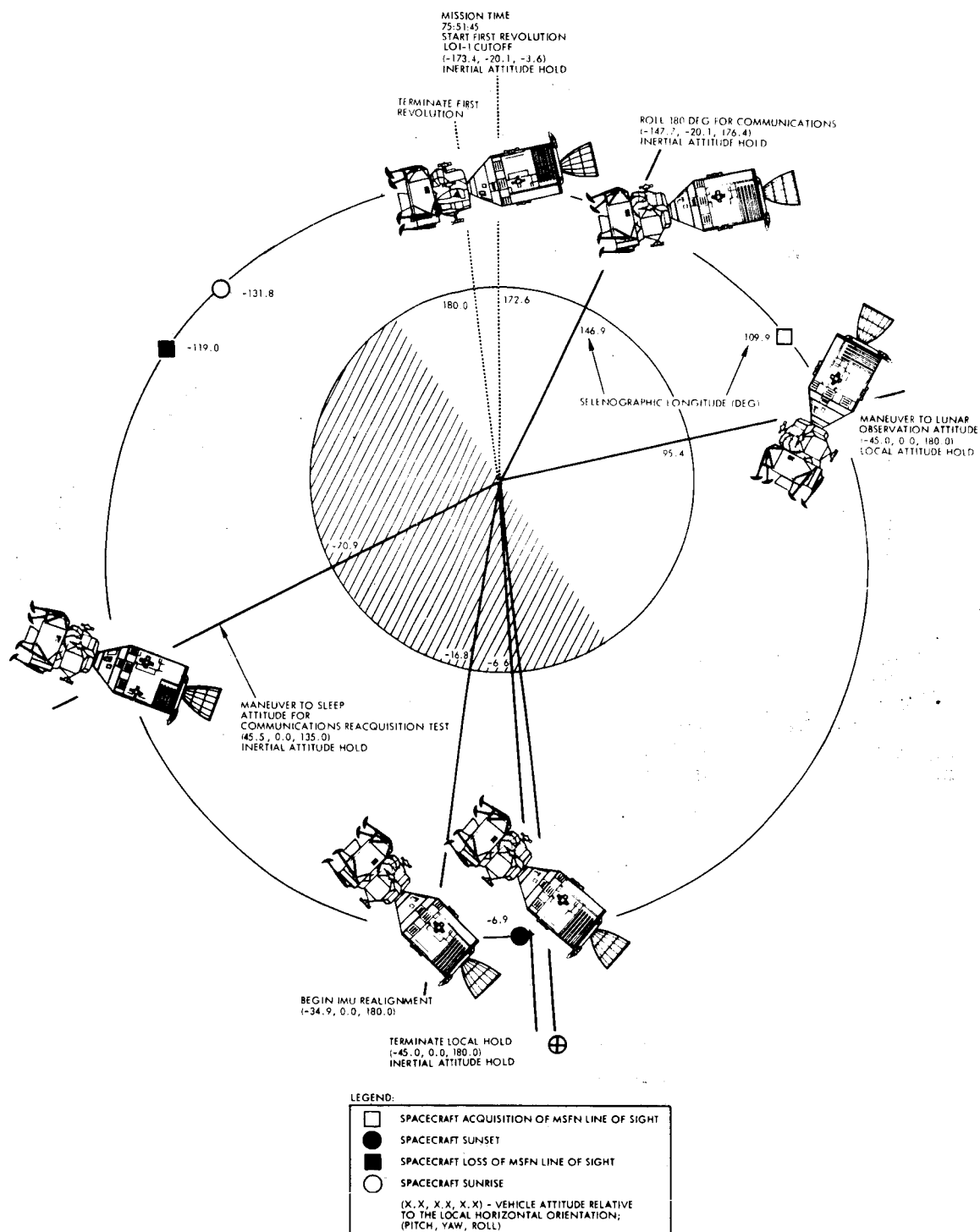


Figure 3. First Revolution Major Events and Attitudes

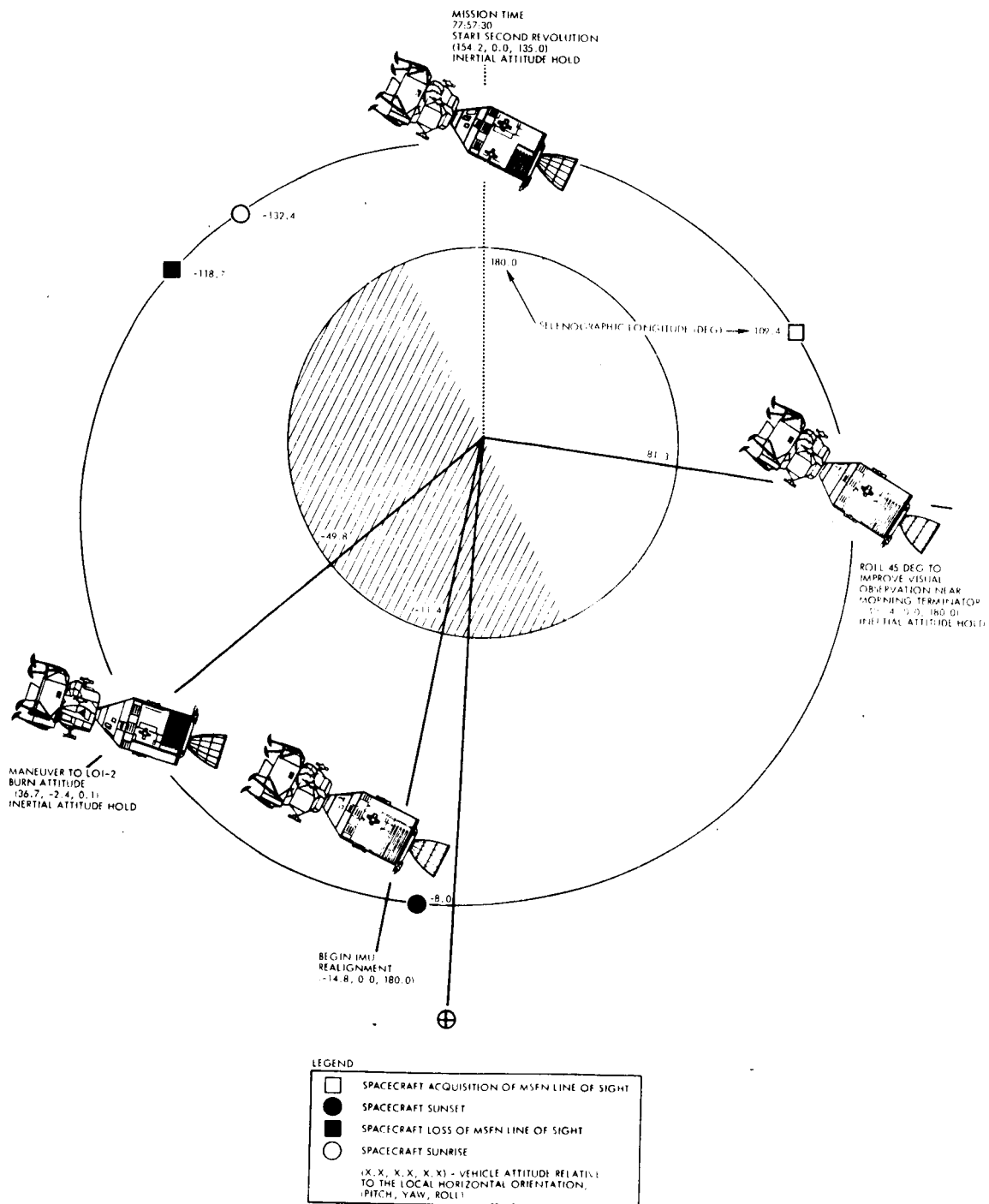


Figure 4. Second Revolution Major Events and Attitudes

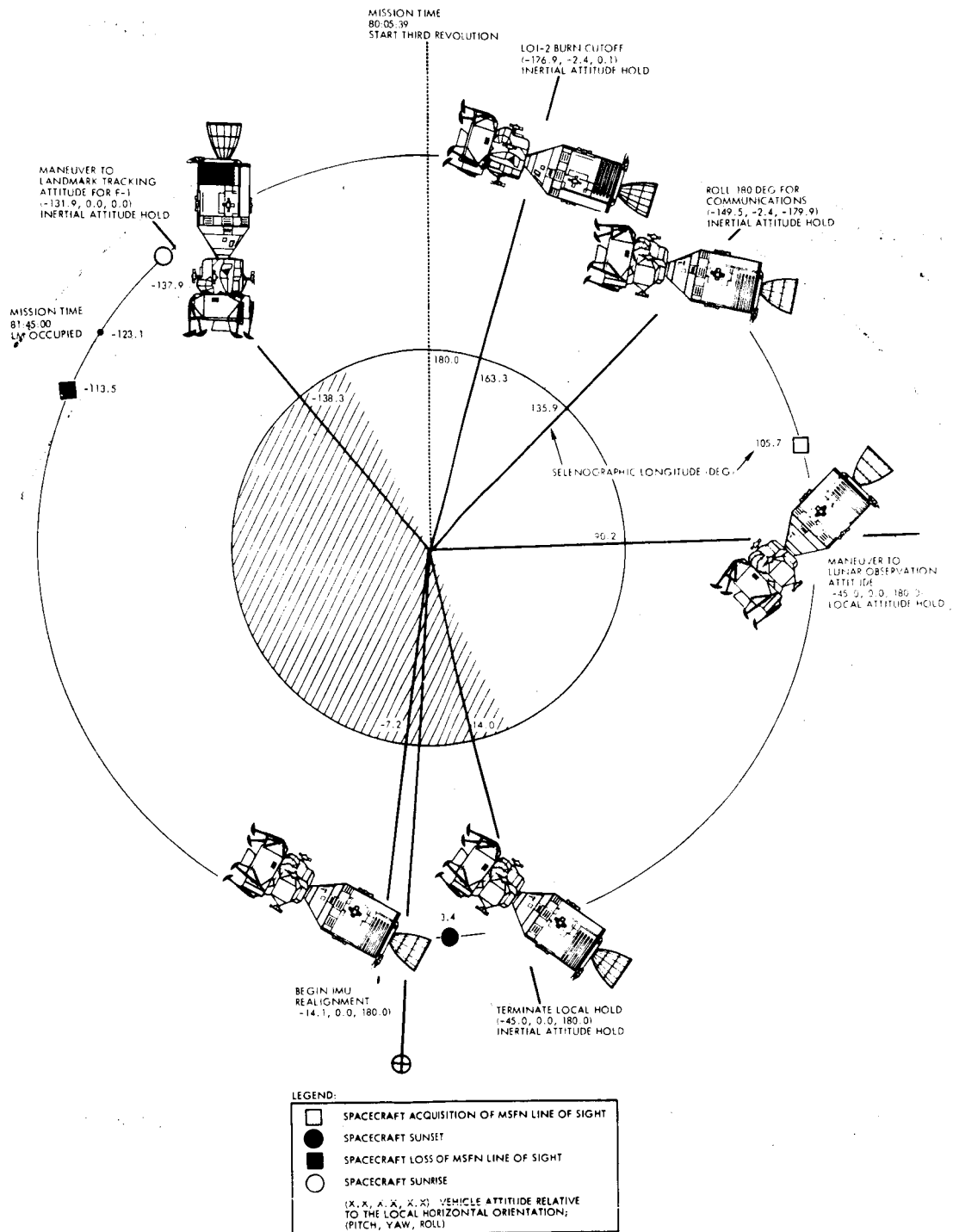


Figure 5. Third Revolution Major Events and Attitudes

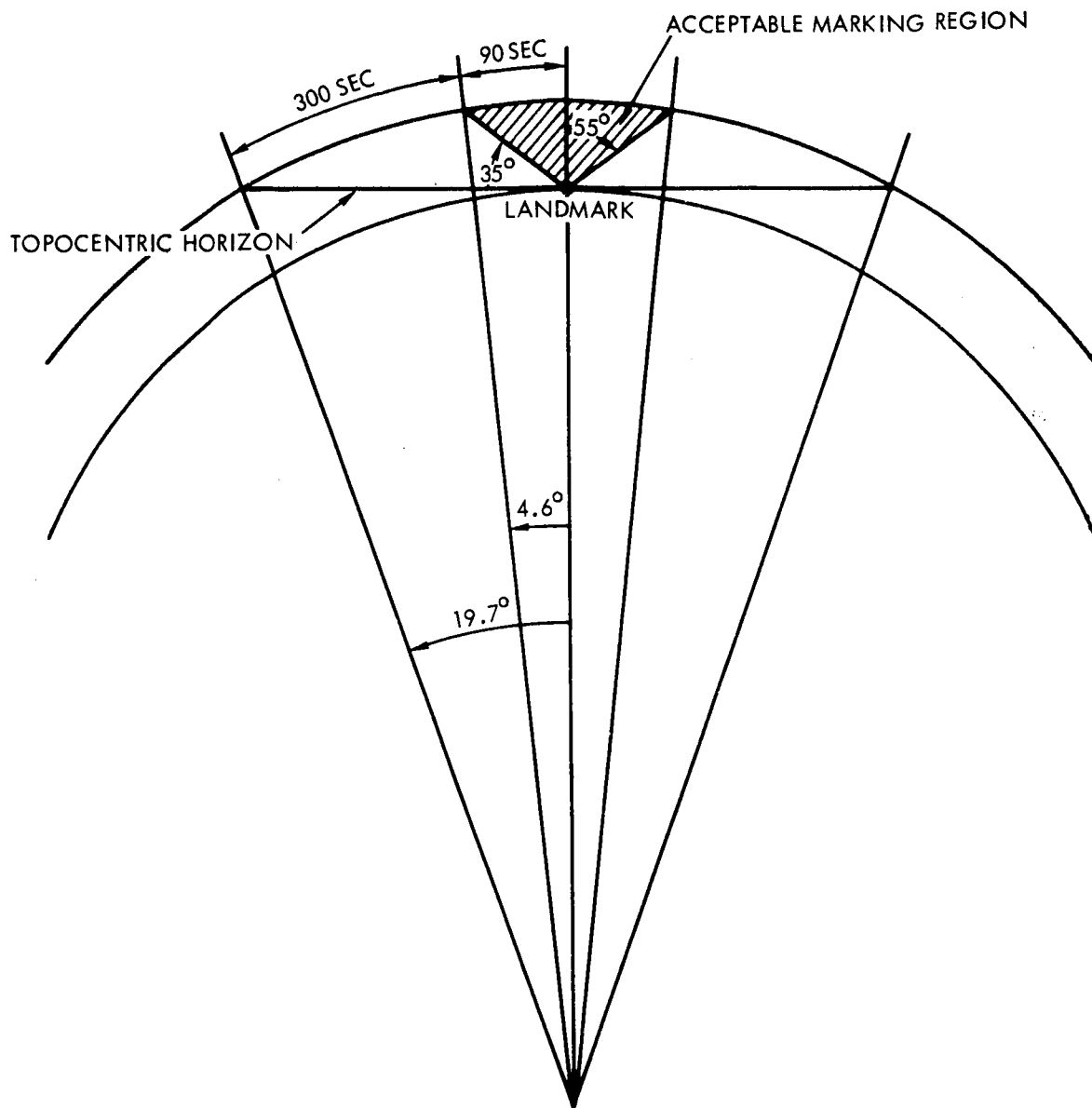


Figure 6. Landmark Tracking Geometry for a 60-Nautical Mile Circular Lunar Orbit

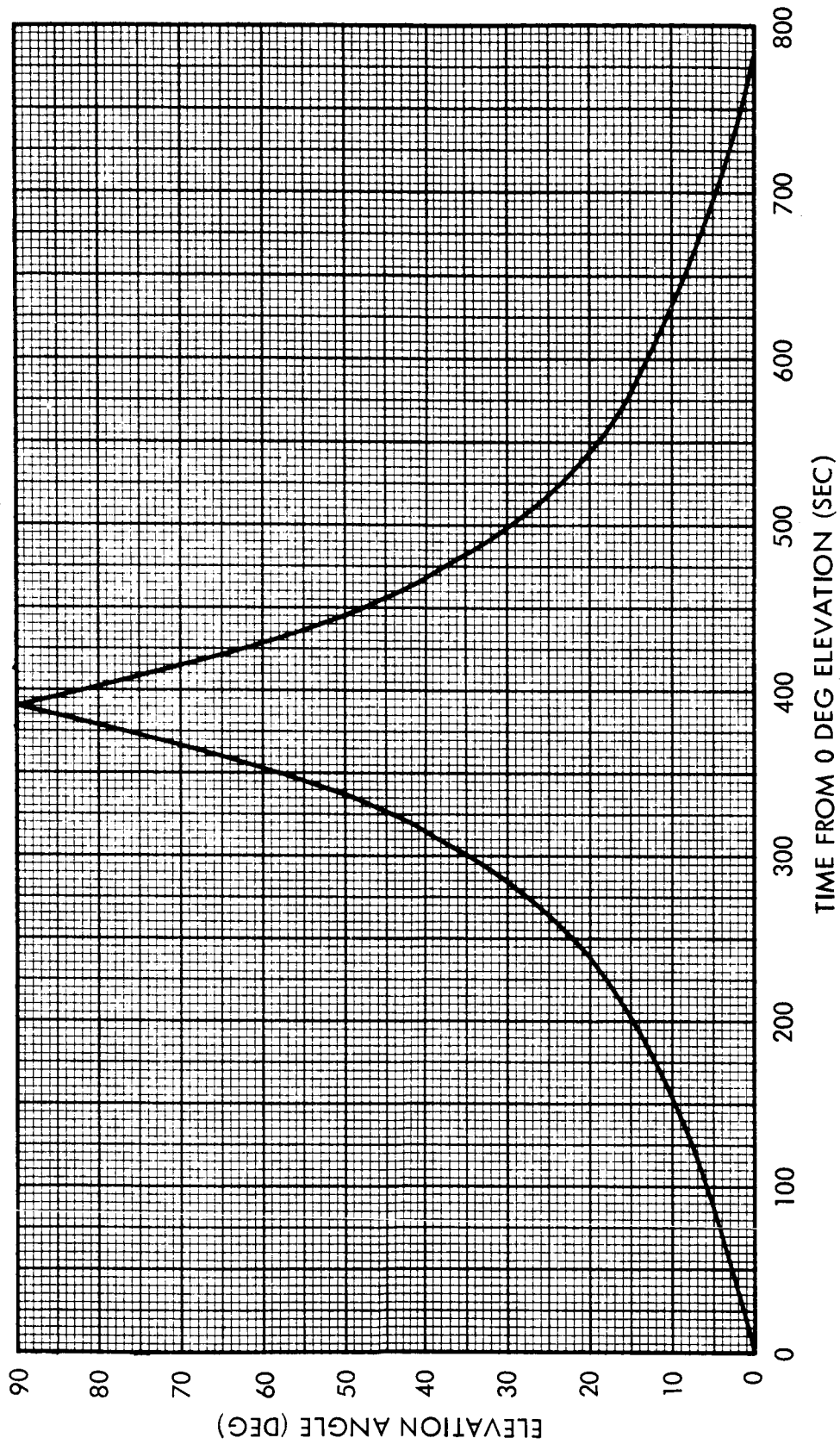


Figure 7. Elevation Angle versus Time Curve for In-plane Landmark

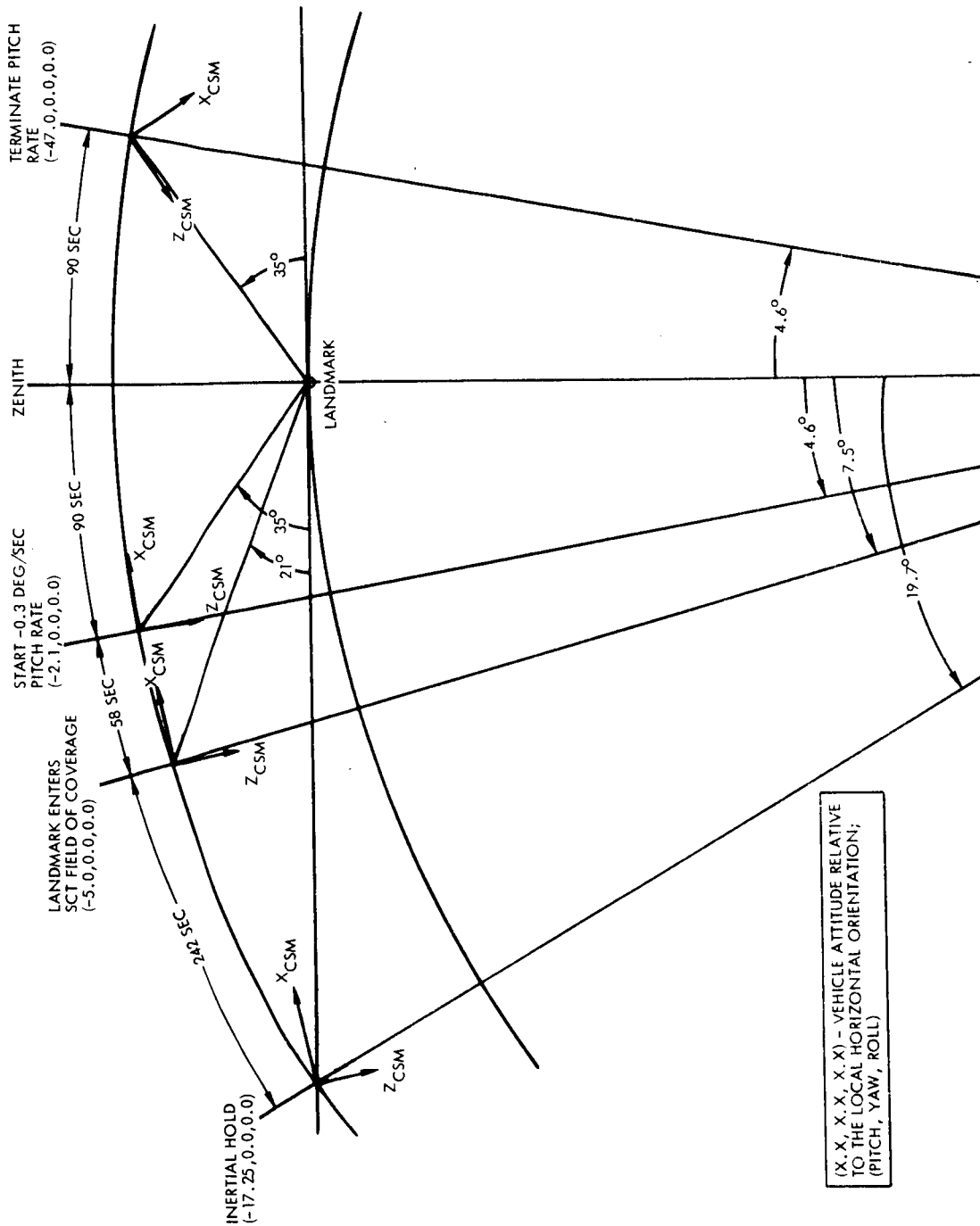


Figure 8. Tracking Geometry for Mode I Landmark Tracking

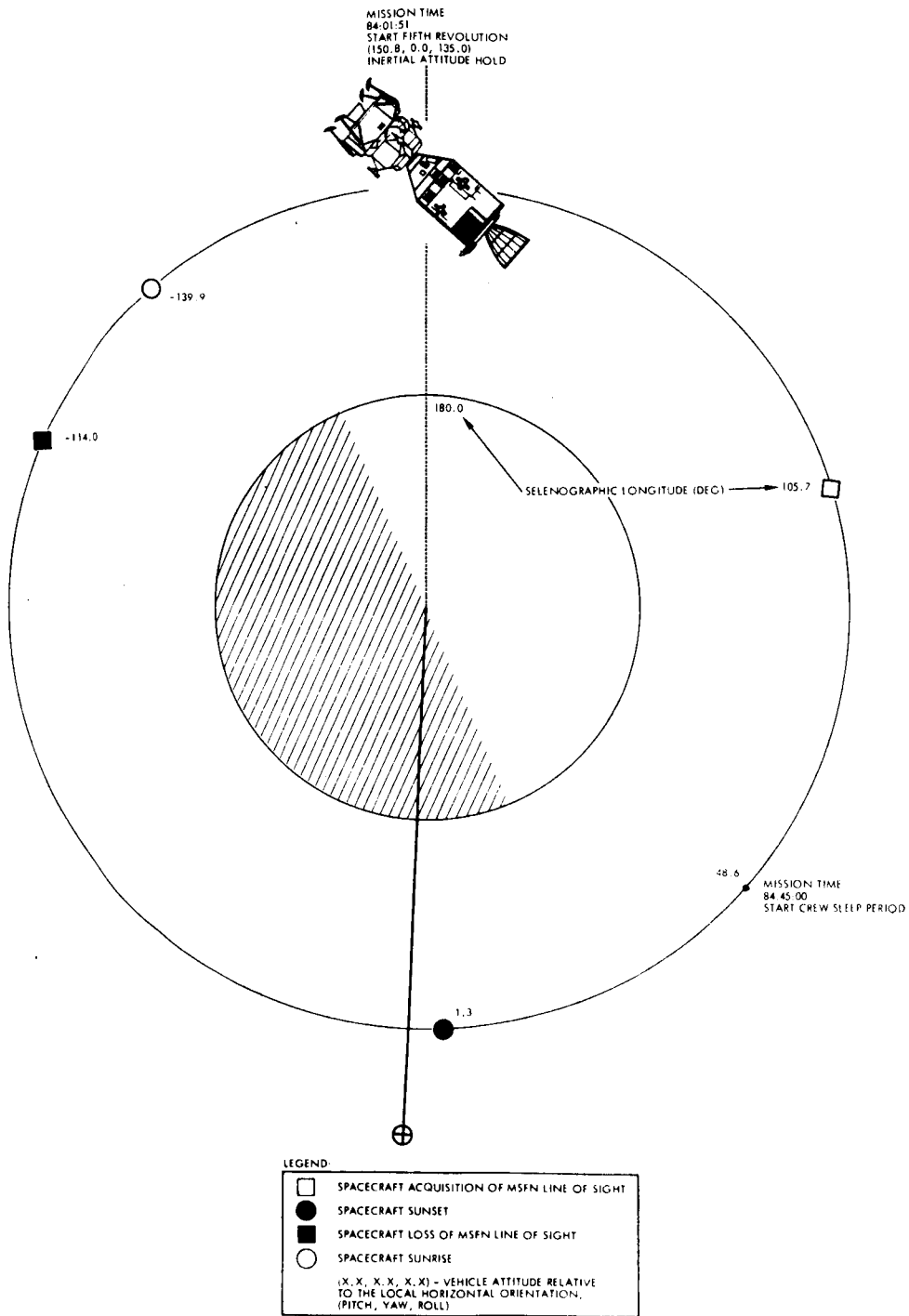


Figure 10. Fifth Revolution Major Events and Attitudes

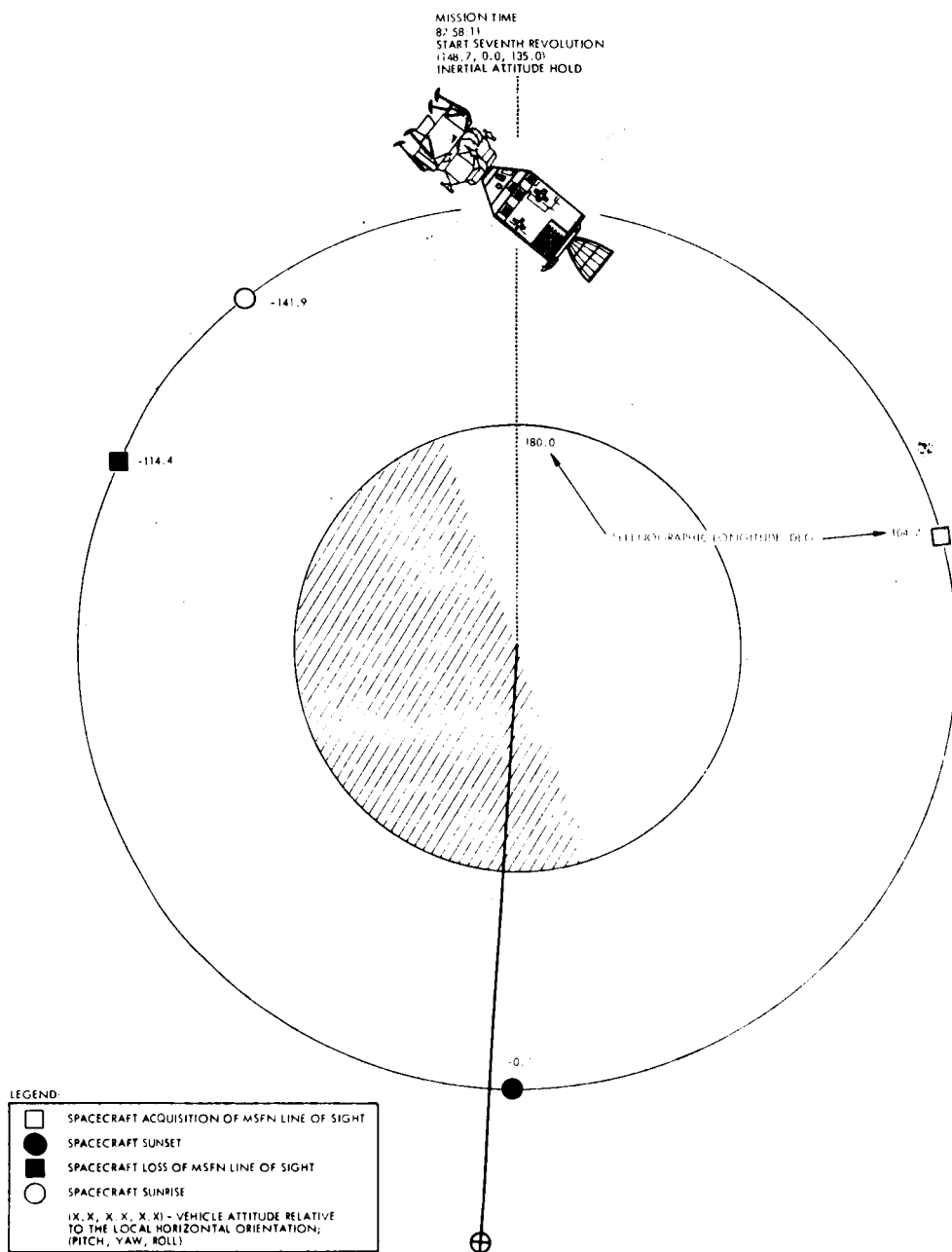


Figure 12. Seventh Revolution Major Events and Attitudes

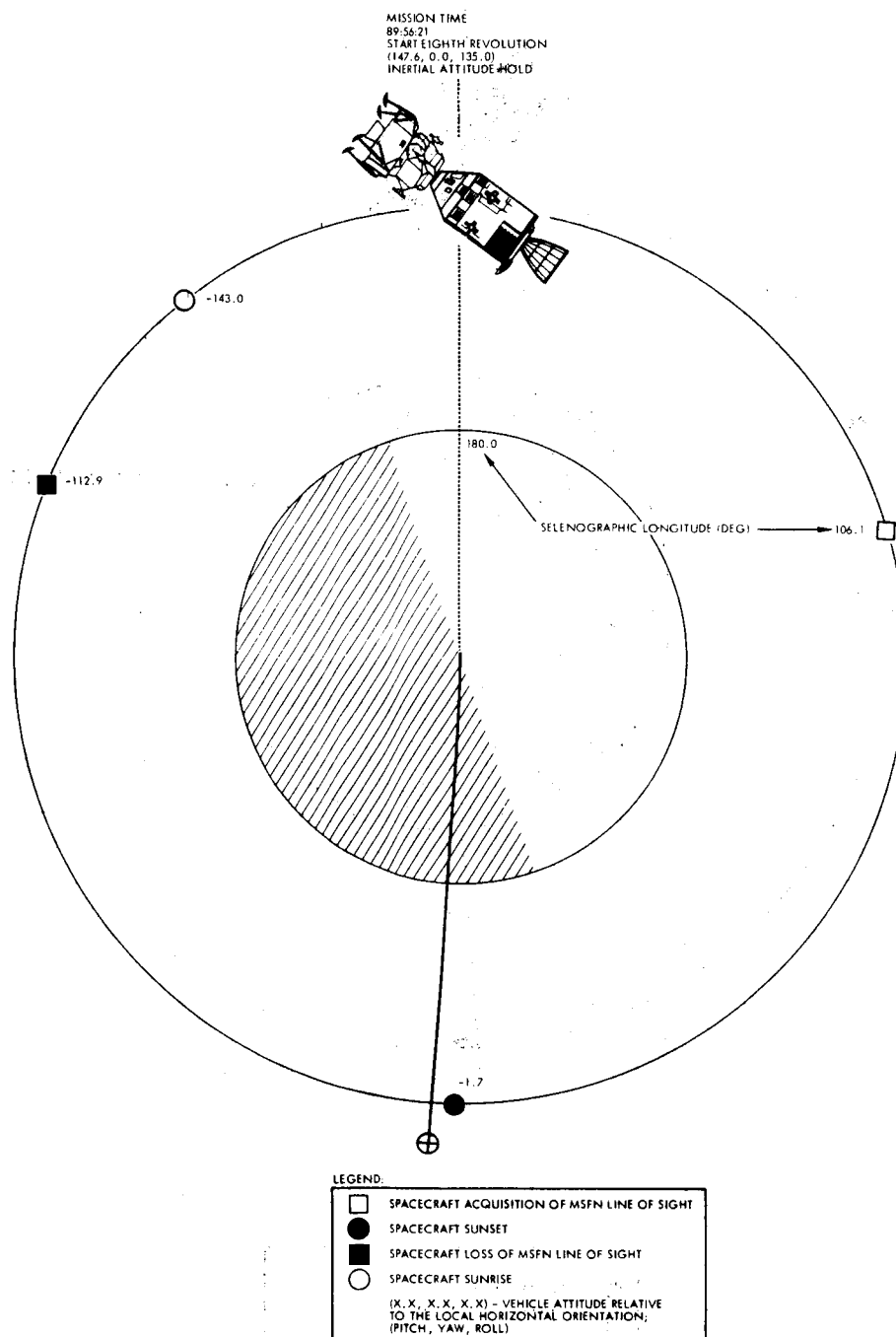


Figure 13. Eighth Revolution Major Events and Attitudes

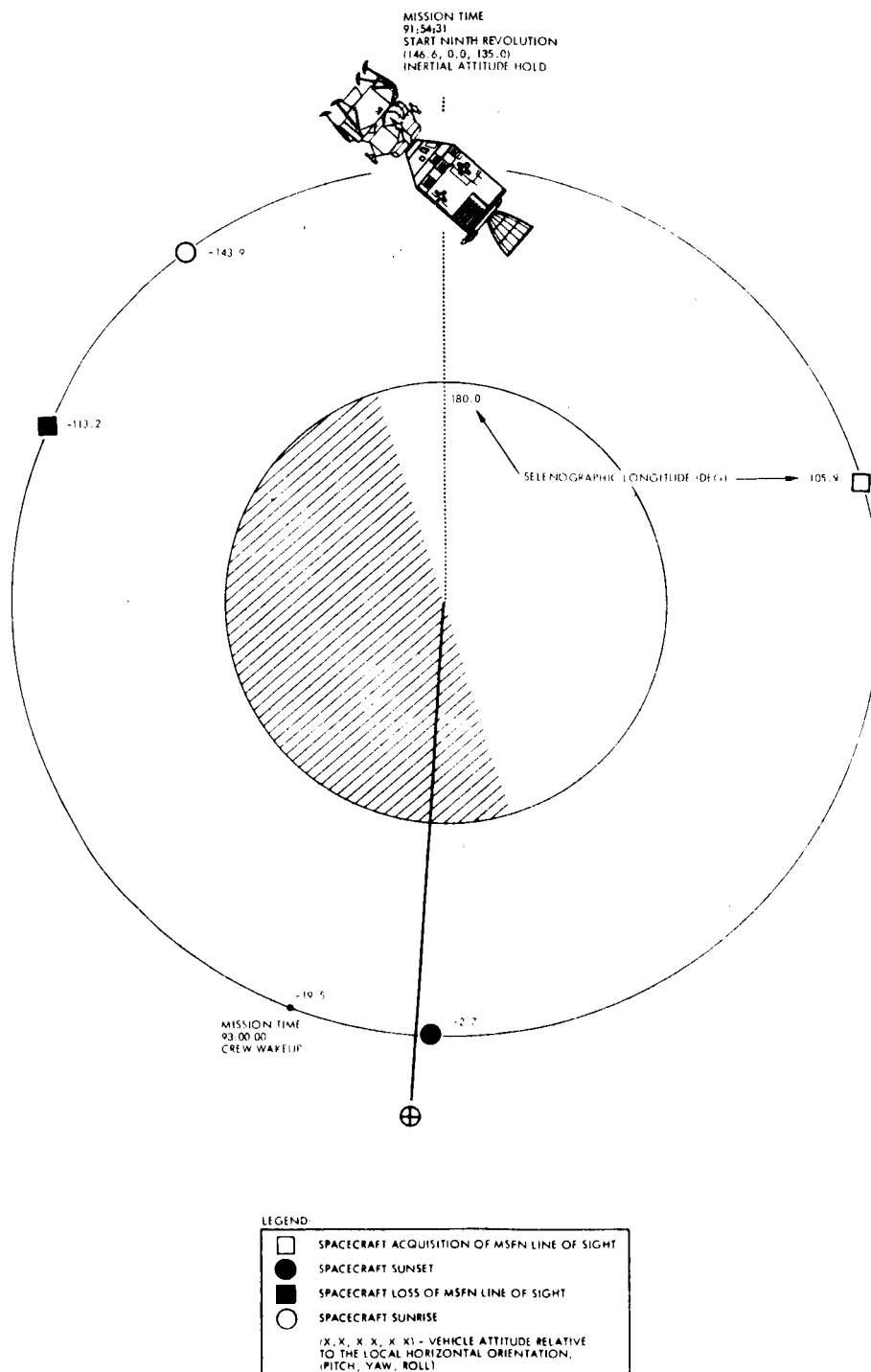


Figure 14. Ninth Revolution Major Events and Attitudes

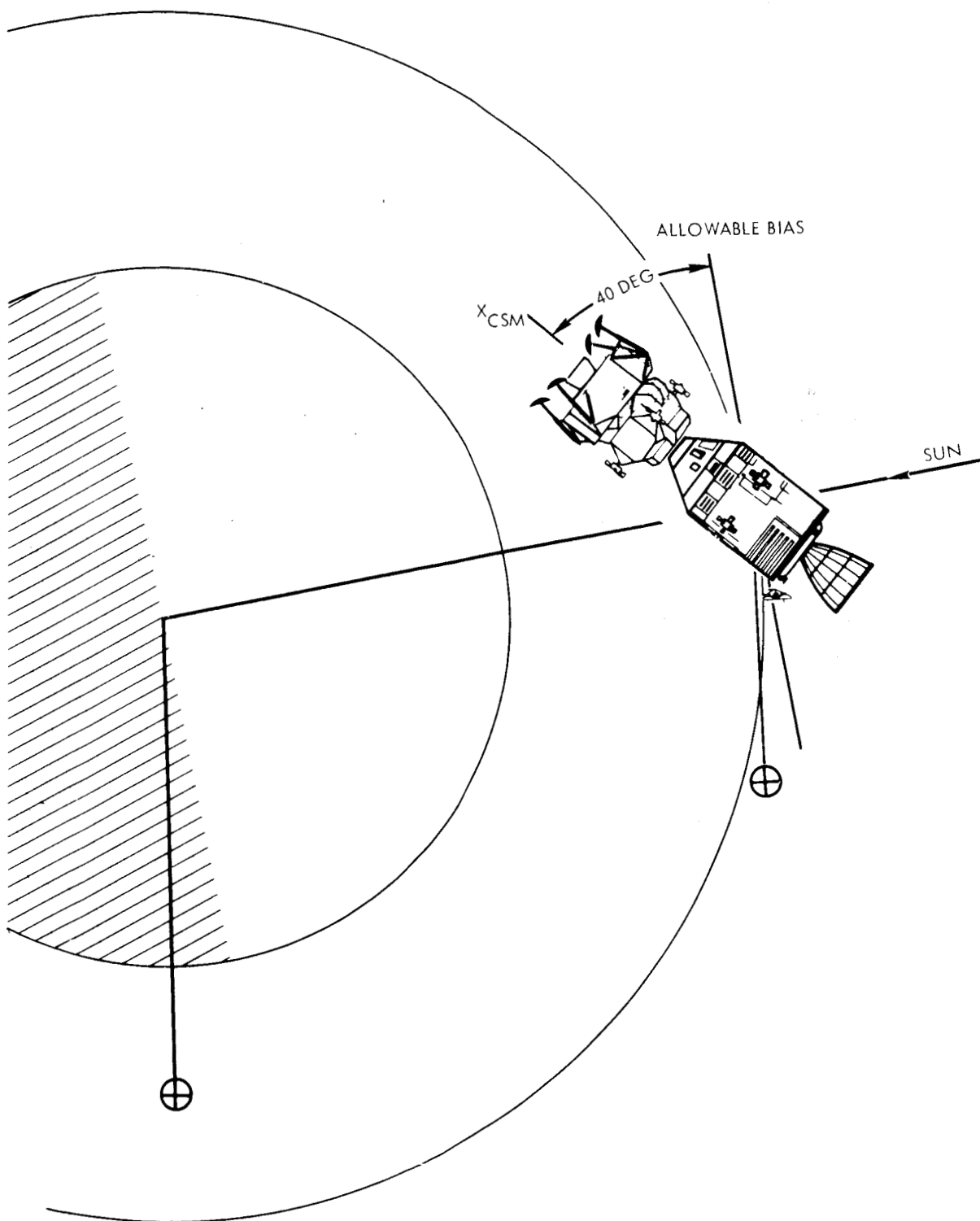


Figure 15. Lunar Orbit Sleep Geometry

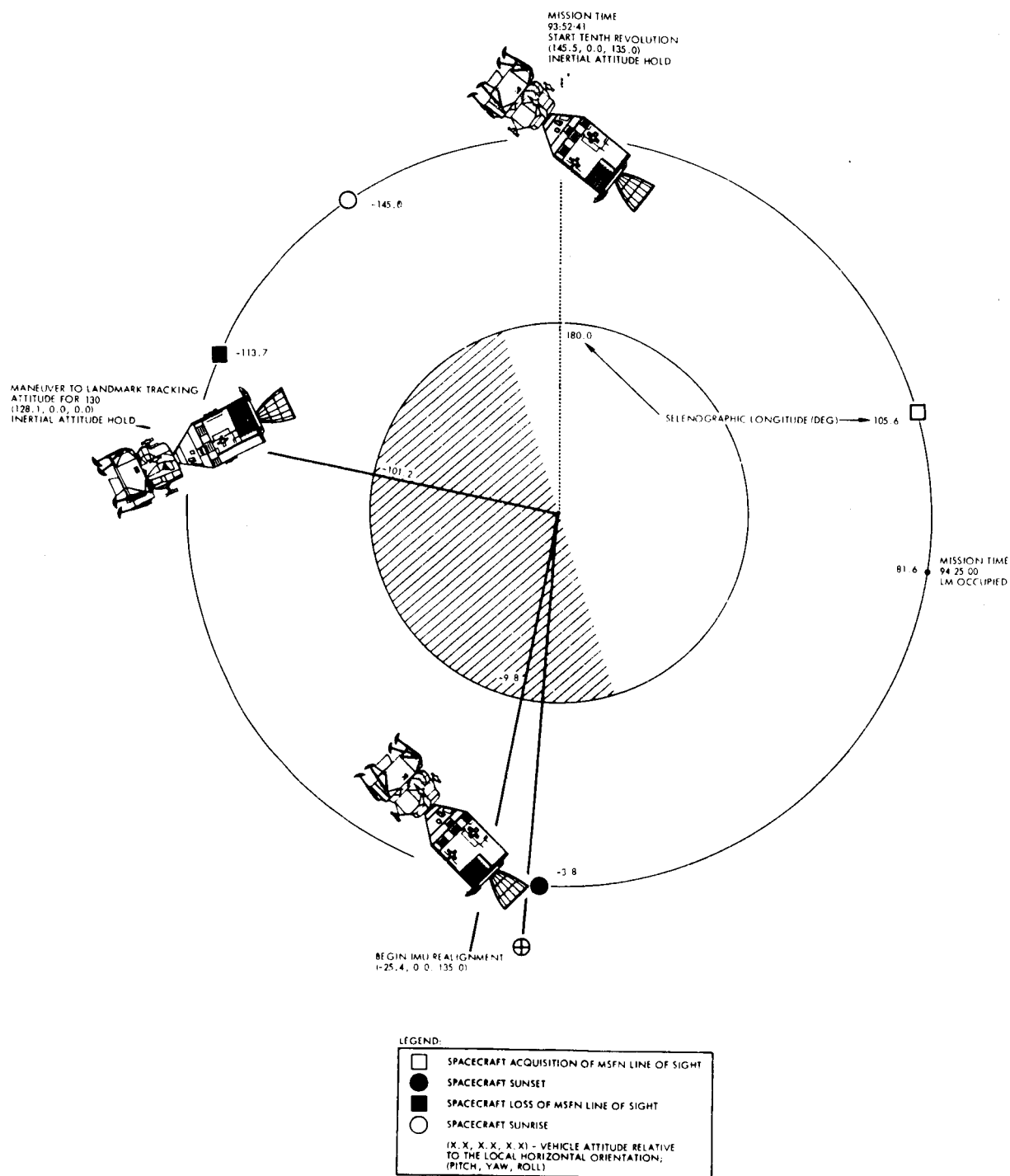


Figure 16. Tenth Revolution Major Events and Attitudes

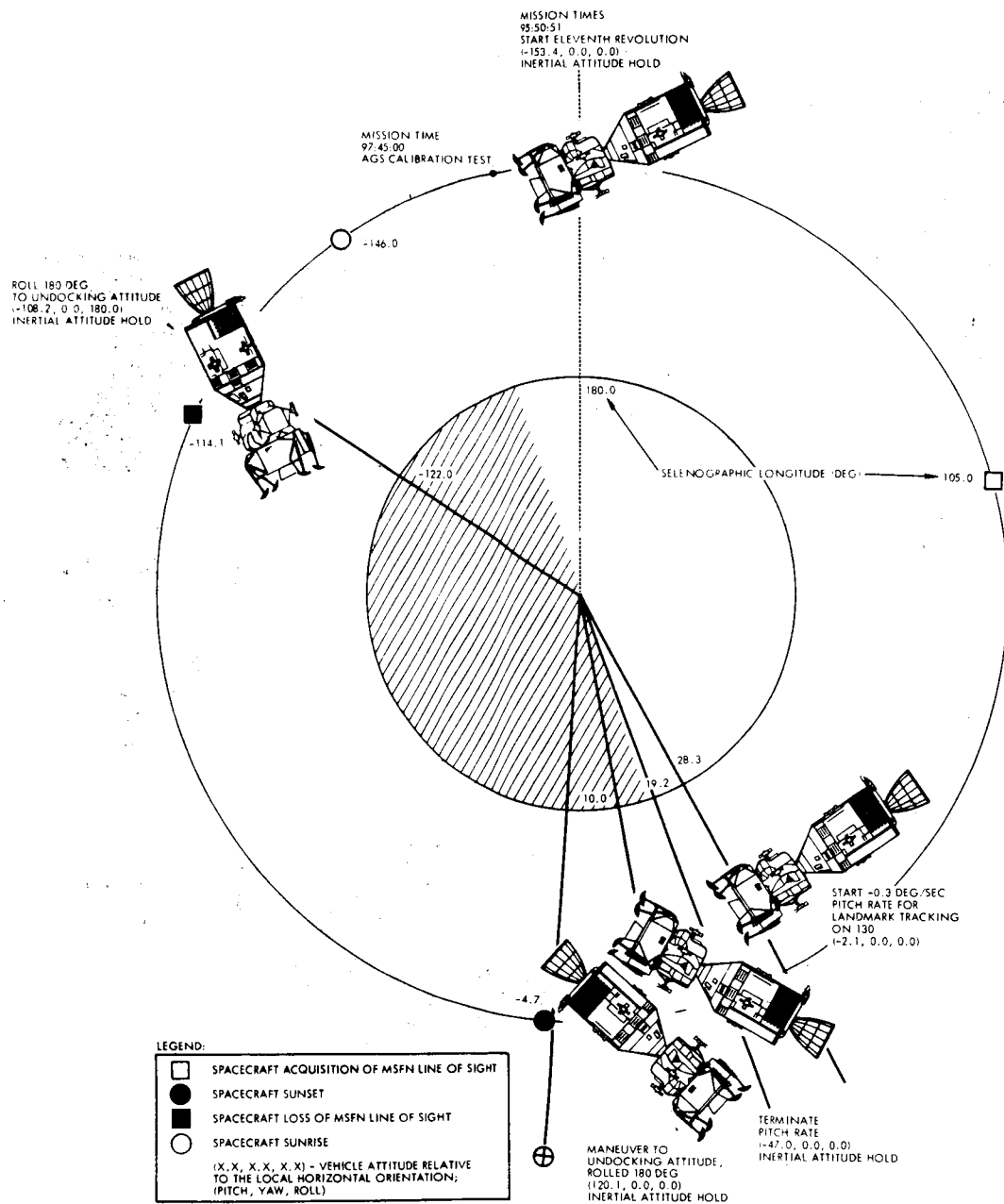


Figure 17. Eleventh Revolution Major Events and Attitudes

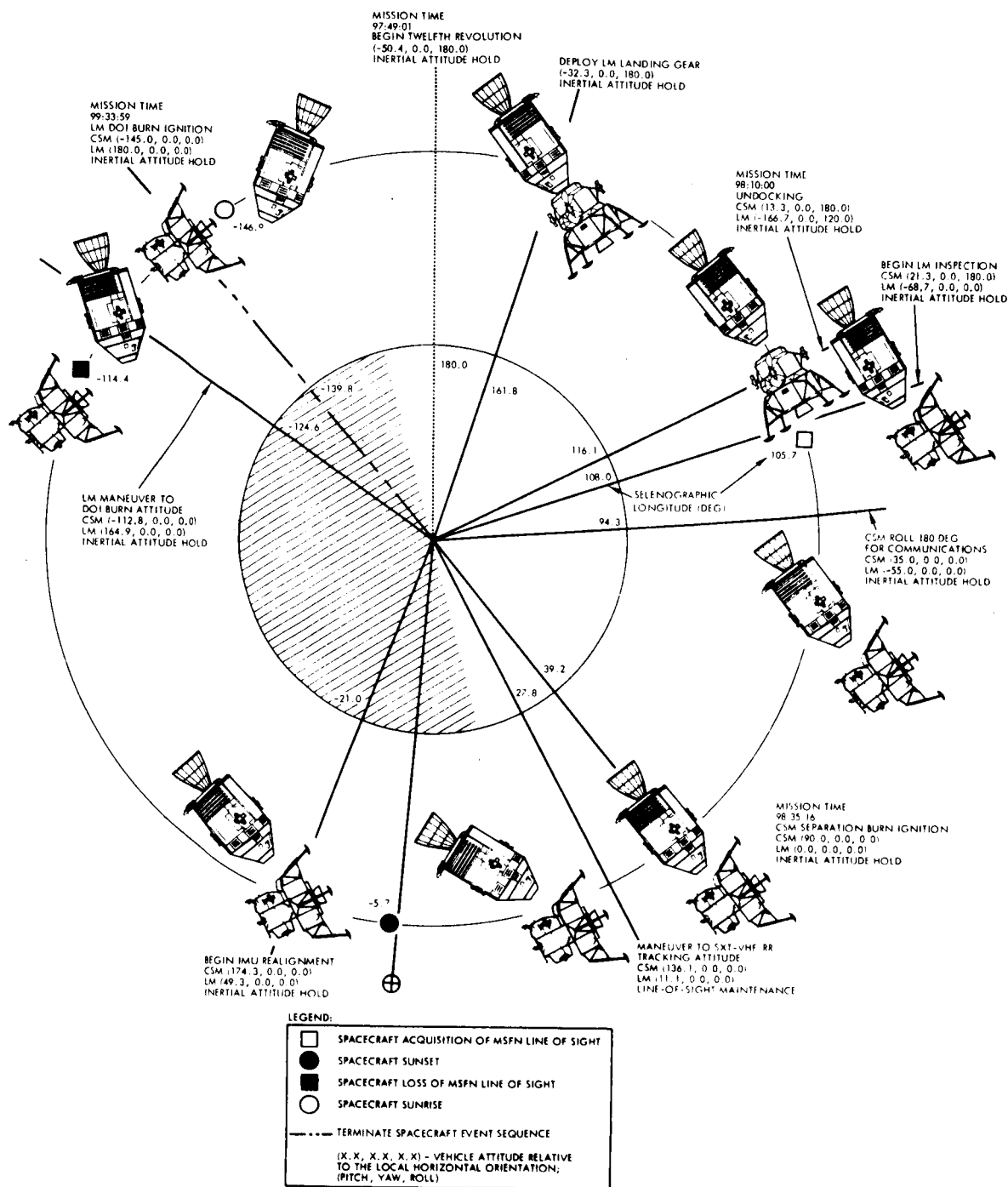


Figure 18. Begin Twelfth Revolution to DOI Burn Ignition

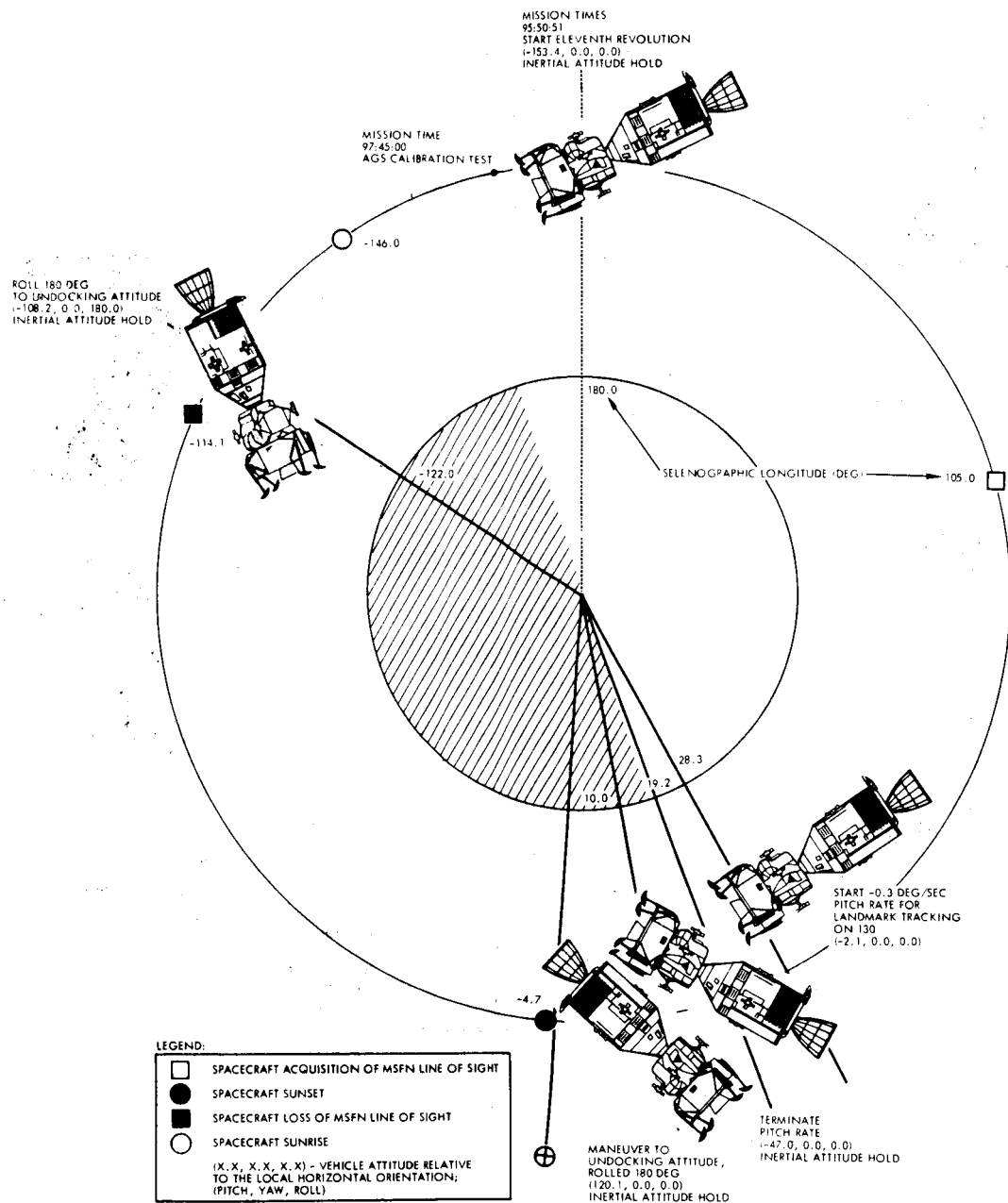


Figure 17. Eleventh Revolution Major Events and Attitudes

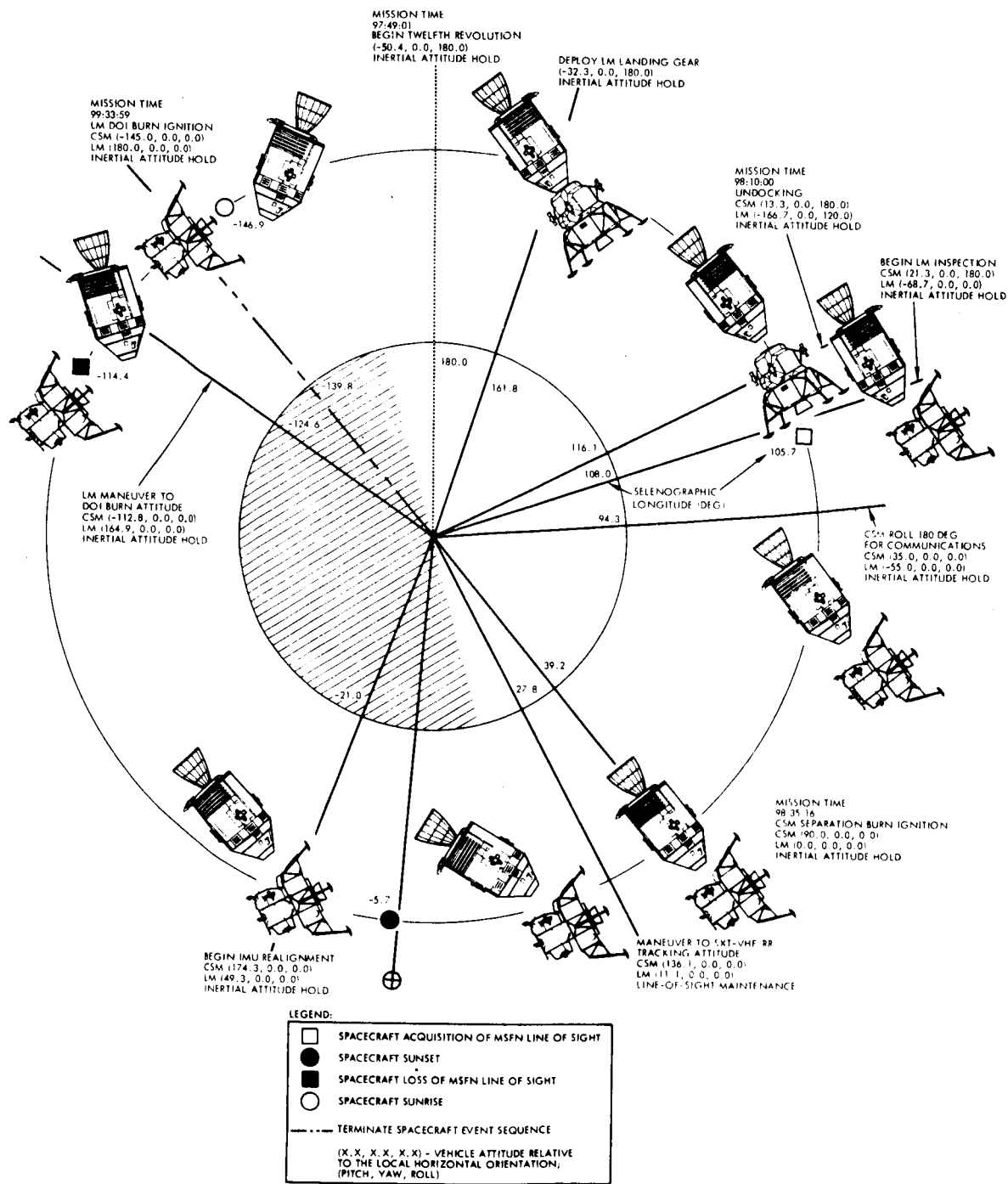


Figure 18. Begin Twelfth Revolution to DOI Burn Ignition

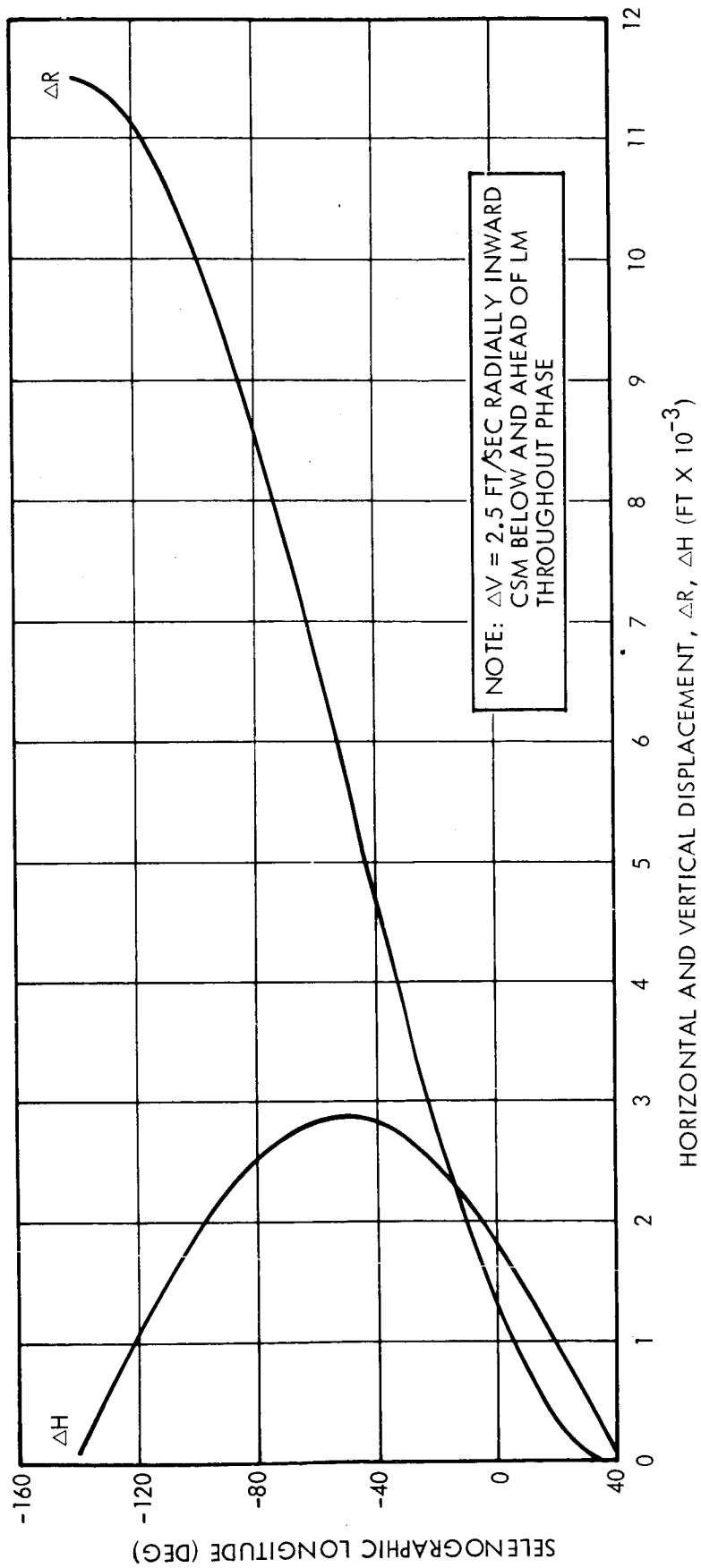


Figure 19. CSM/LM Relative Motion from Separation to DOI (LM Fixed)

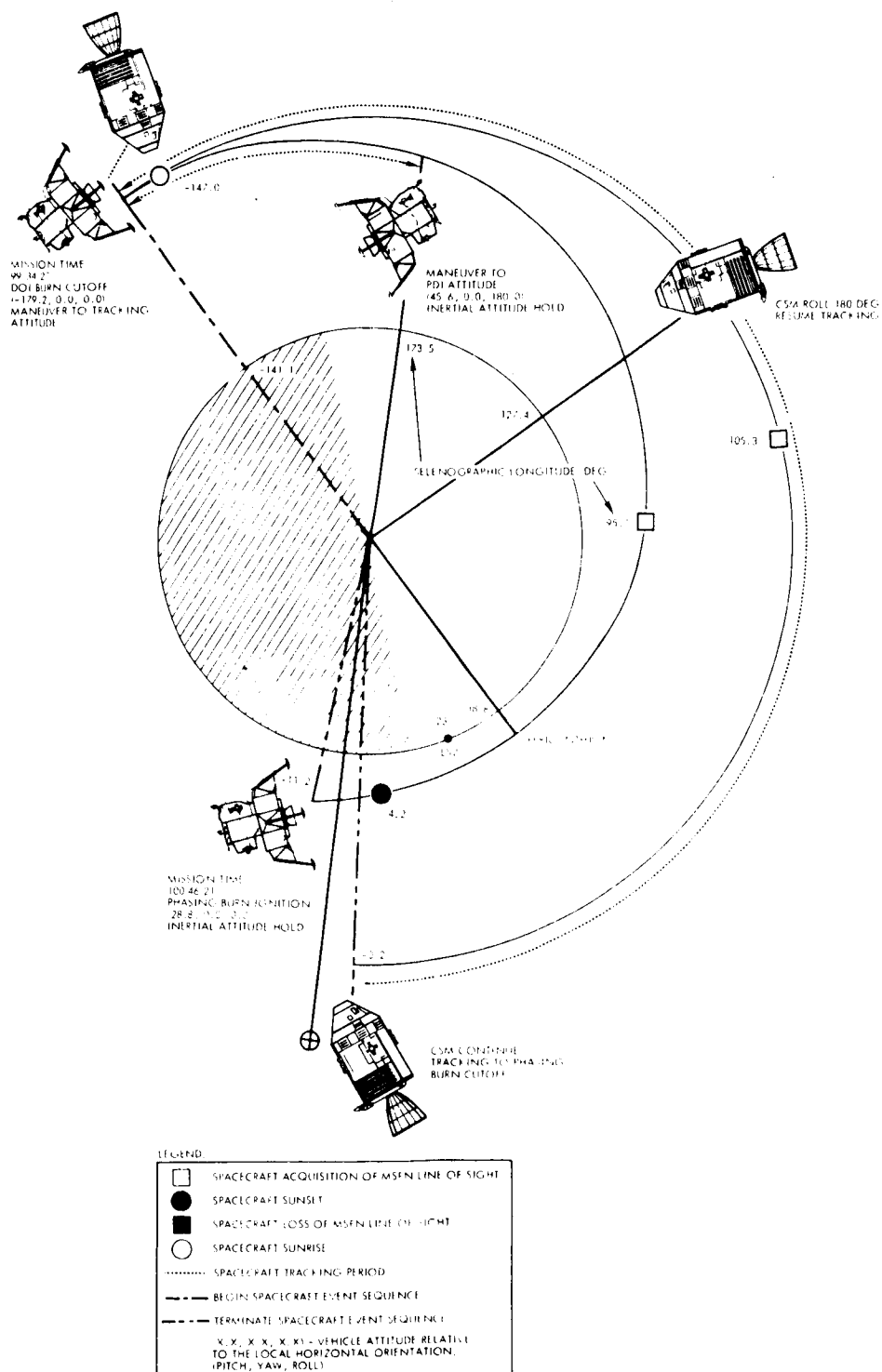


Figure 20. DOI Burn Cutoff to Phasing Burn Ignition

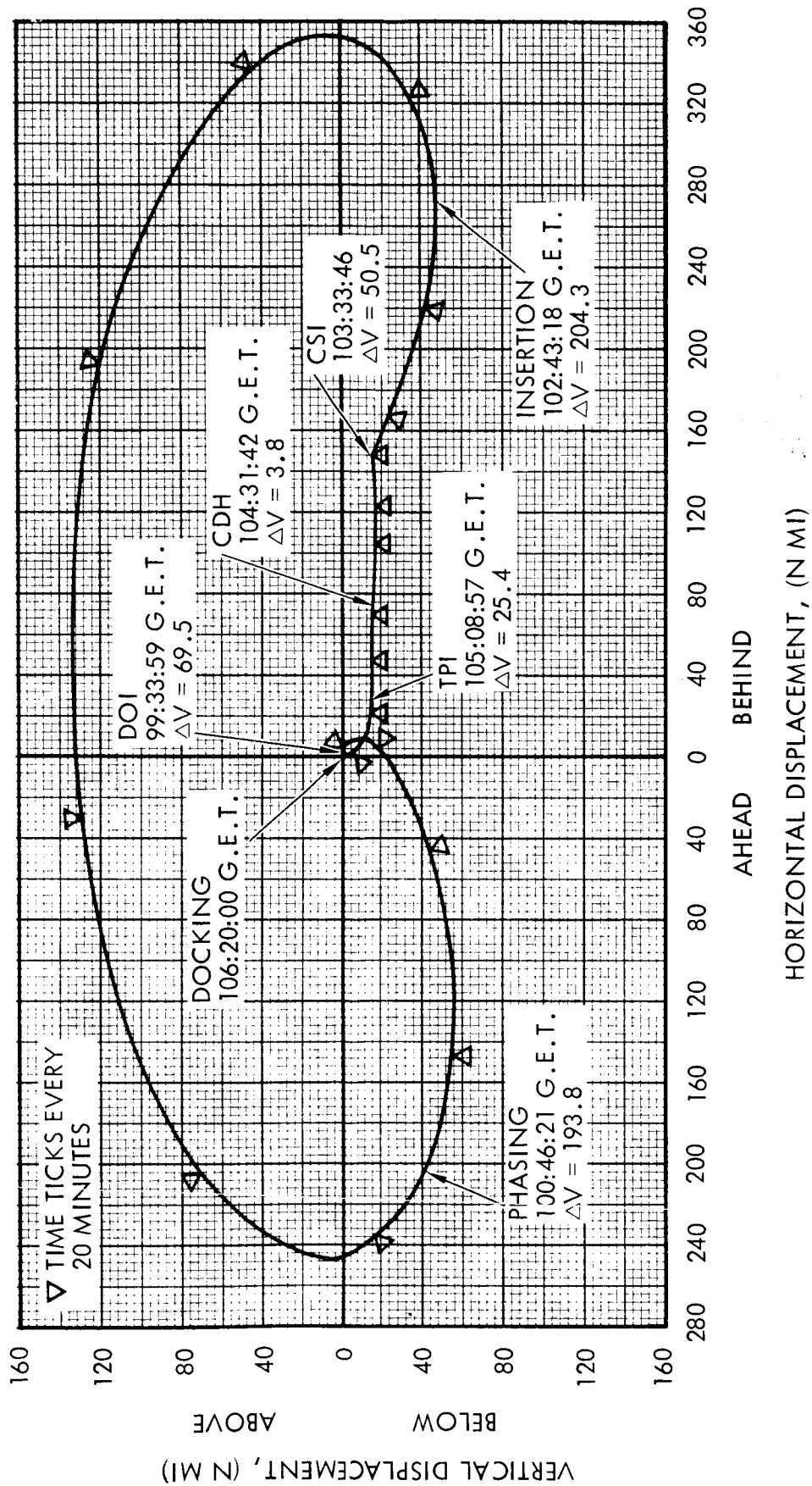


Figure 21. CSM-LM Relative Motion from DOI Cutoff to Docking

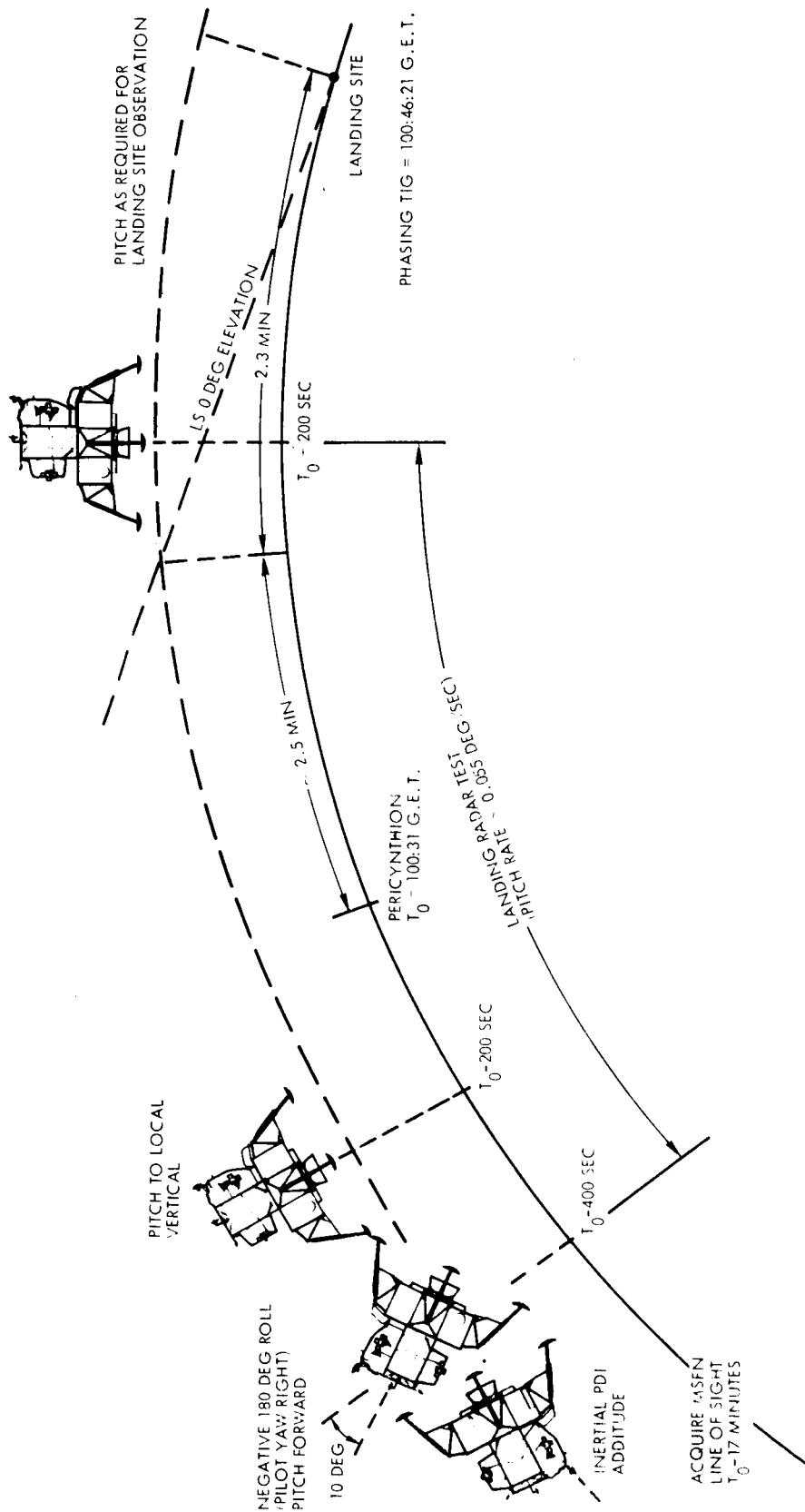


Figure 22. Landing Radar Test Attitude Sequence

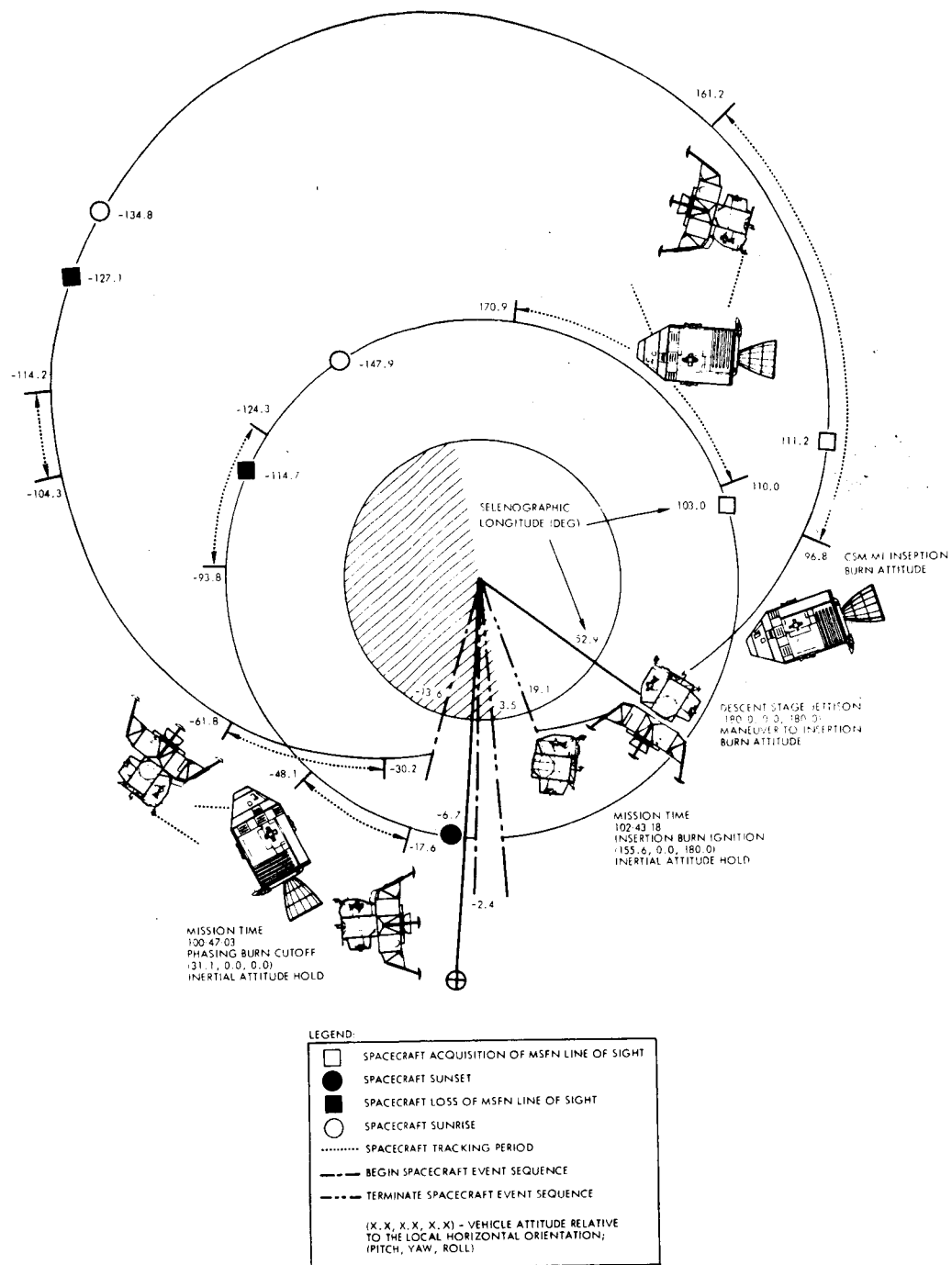


Figure 23. Phasing Burn Cutoff to Insertion Burn Ignition

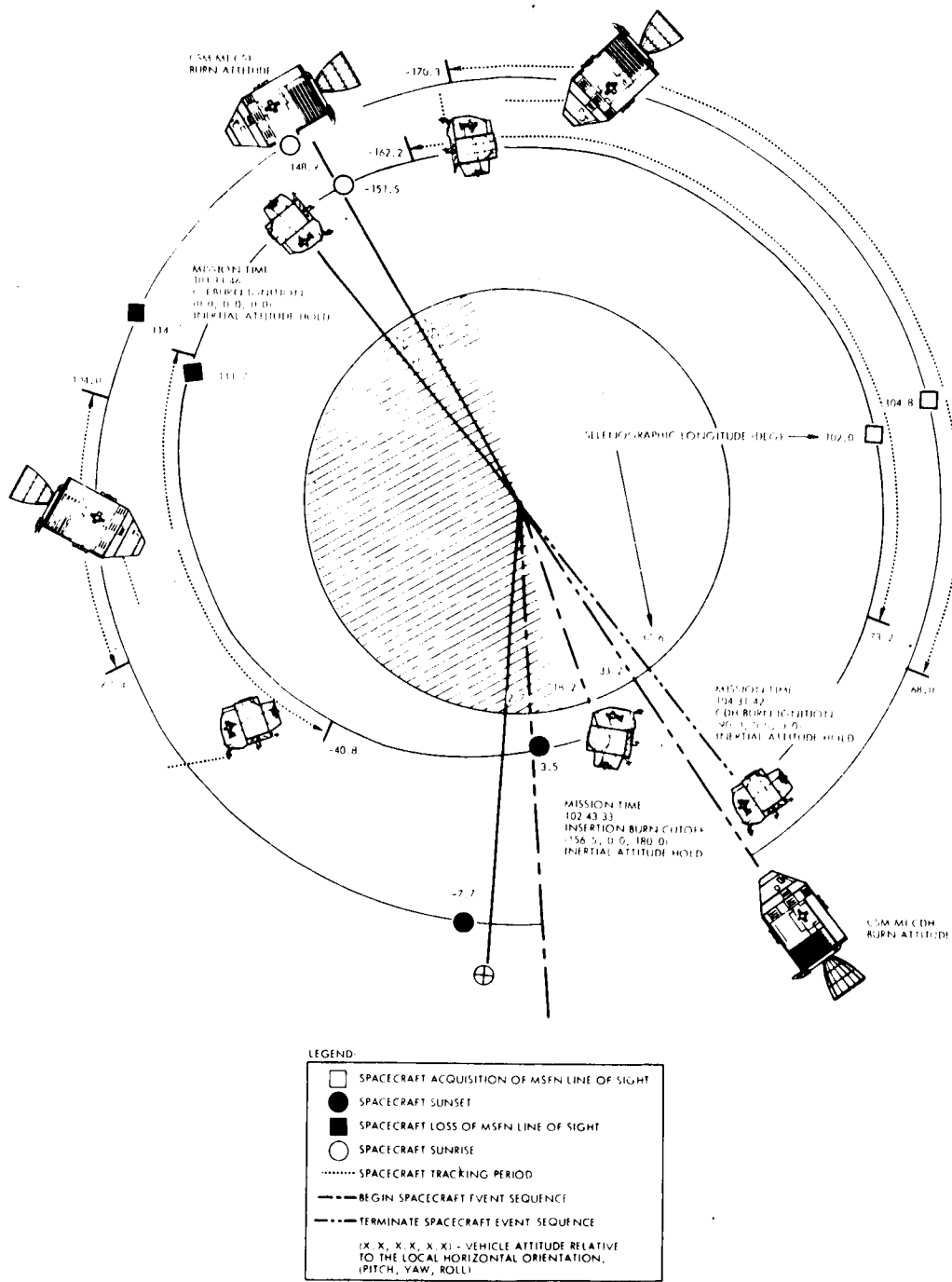


Figure 24. Insertion Burn Cutoff to CDH Burn Ignition

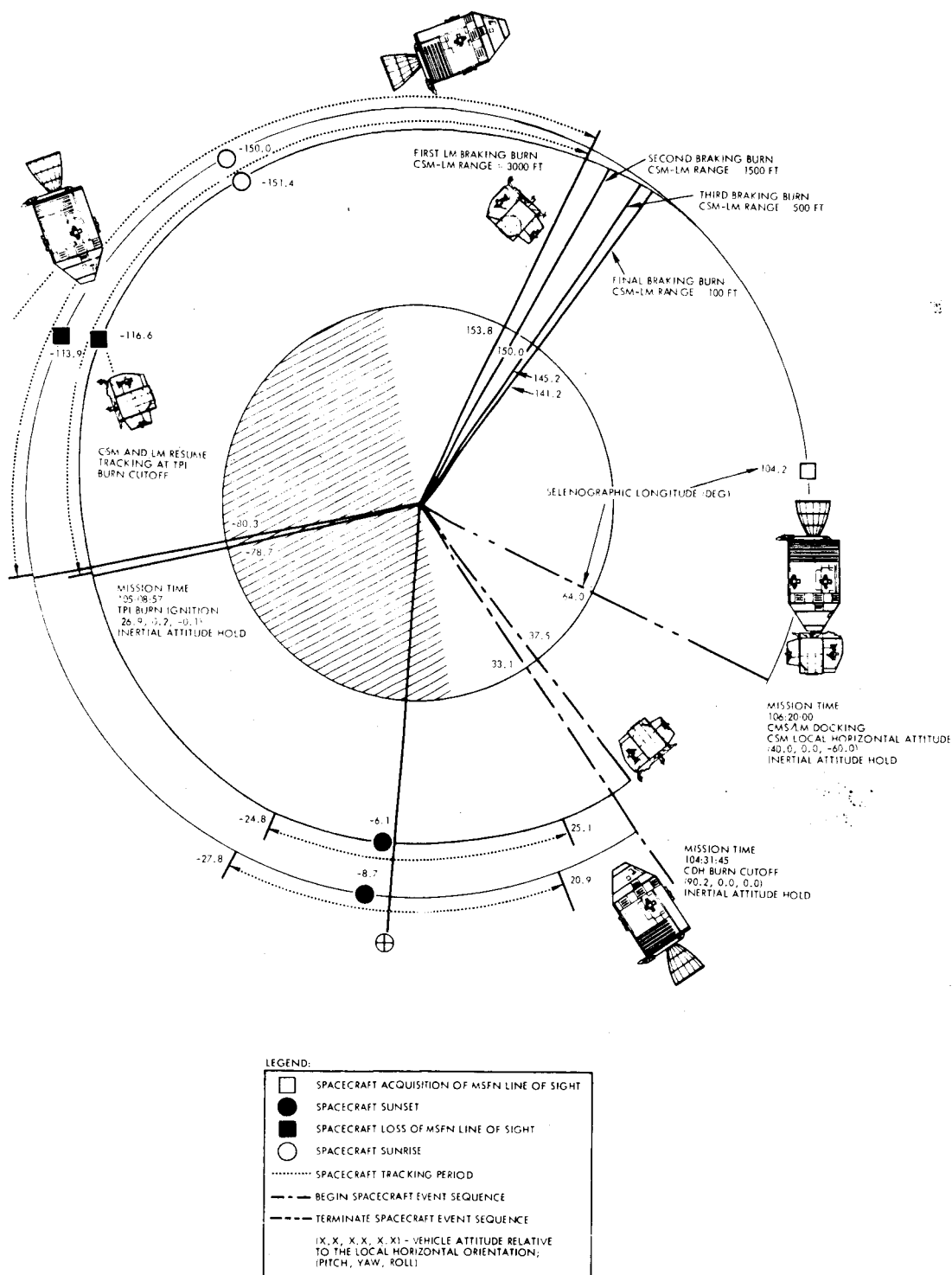


Figure 25. CDH Burn Cutoff to Docking

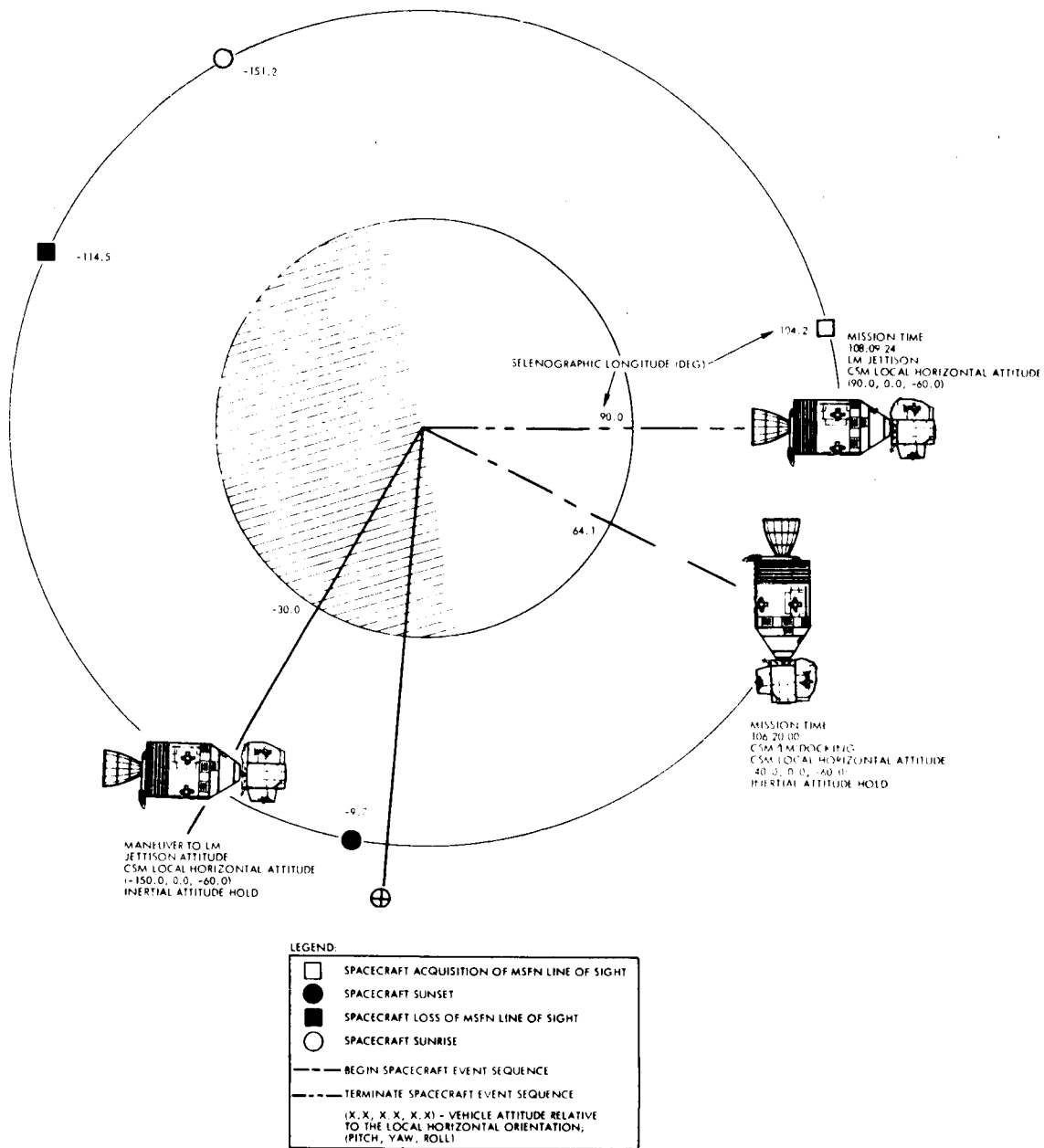


Figure 26. Docking to LM Jettison

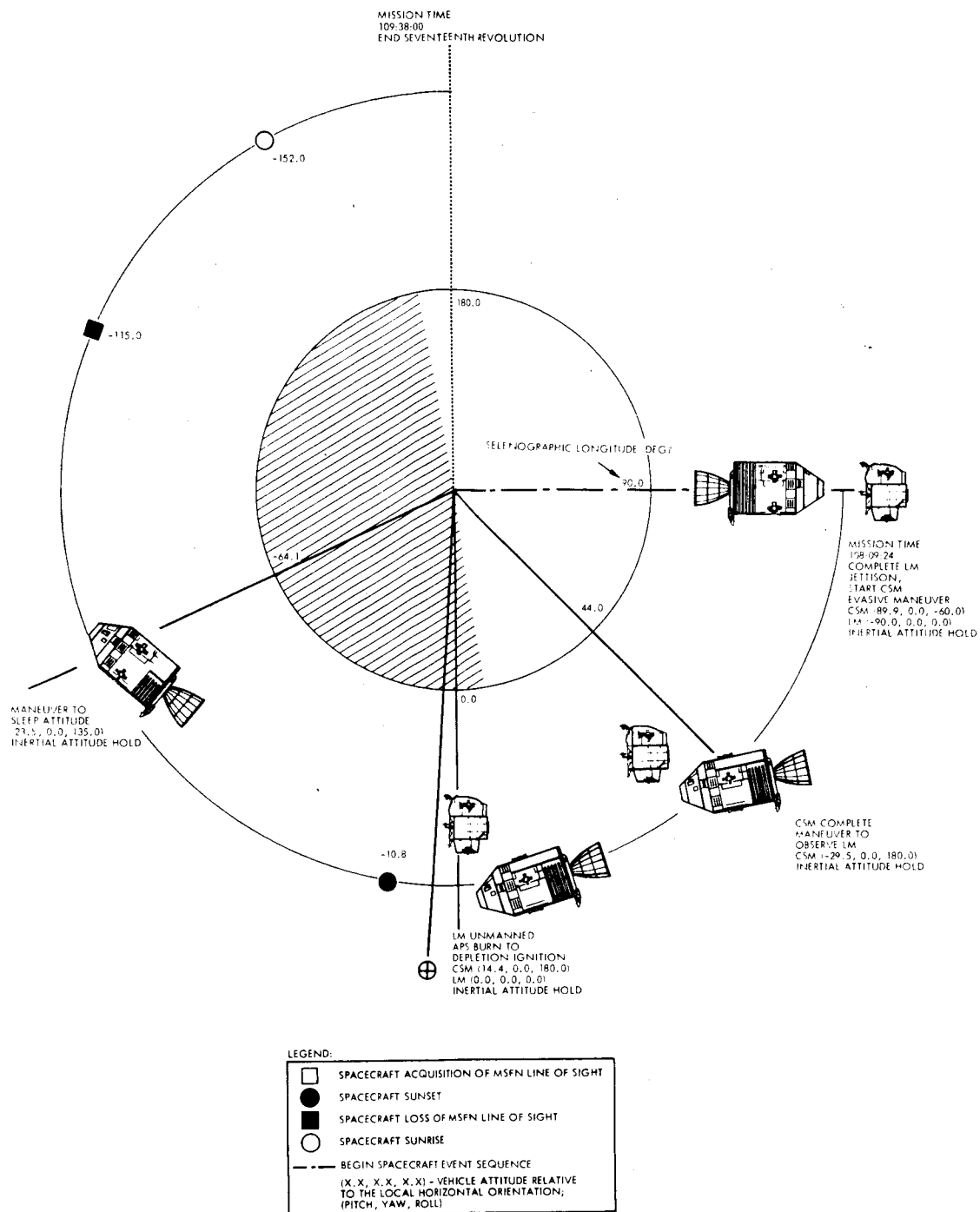


Figure 27. LM Jettison to End of Seventeenth Revolution

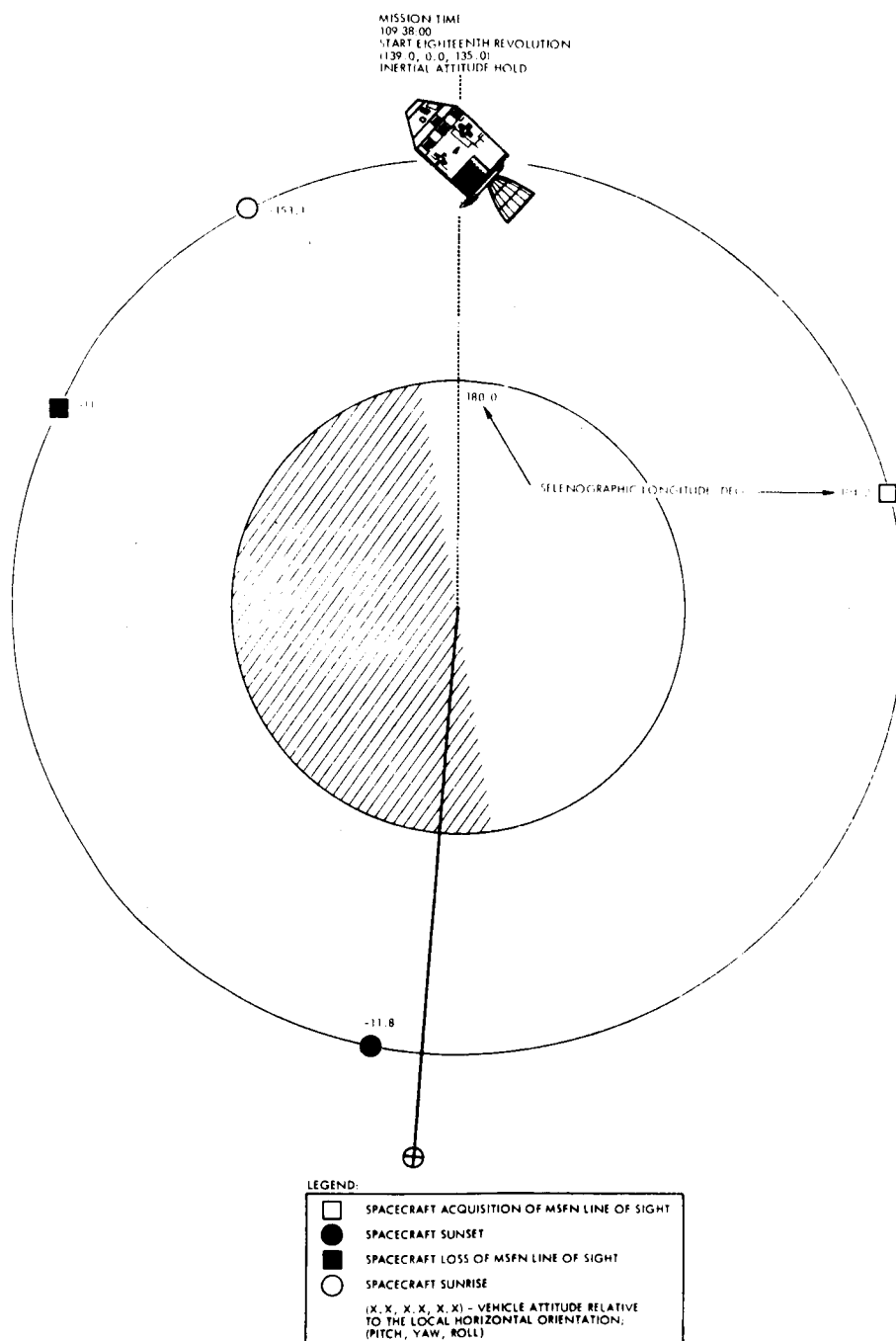


Figure 28. Eighteenth Revolution Major Events and Attitudes

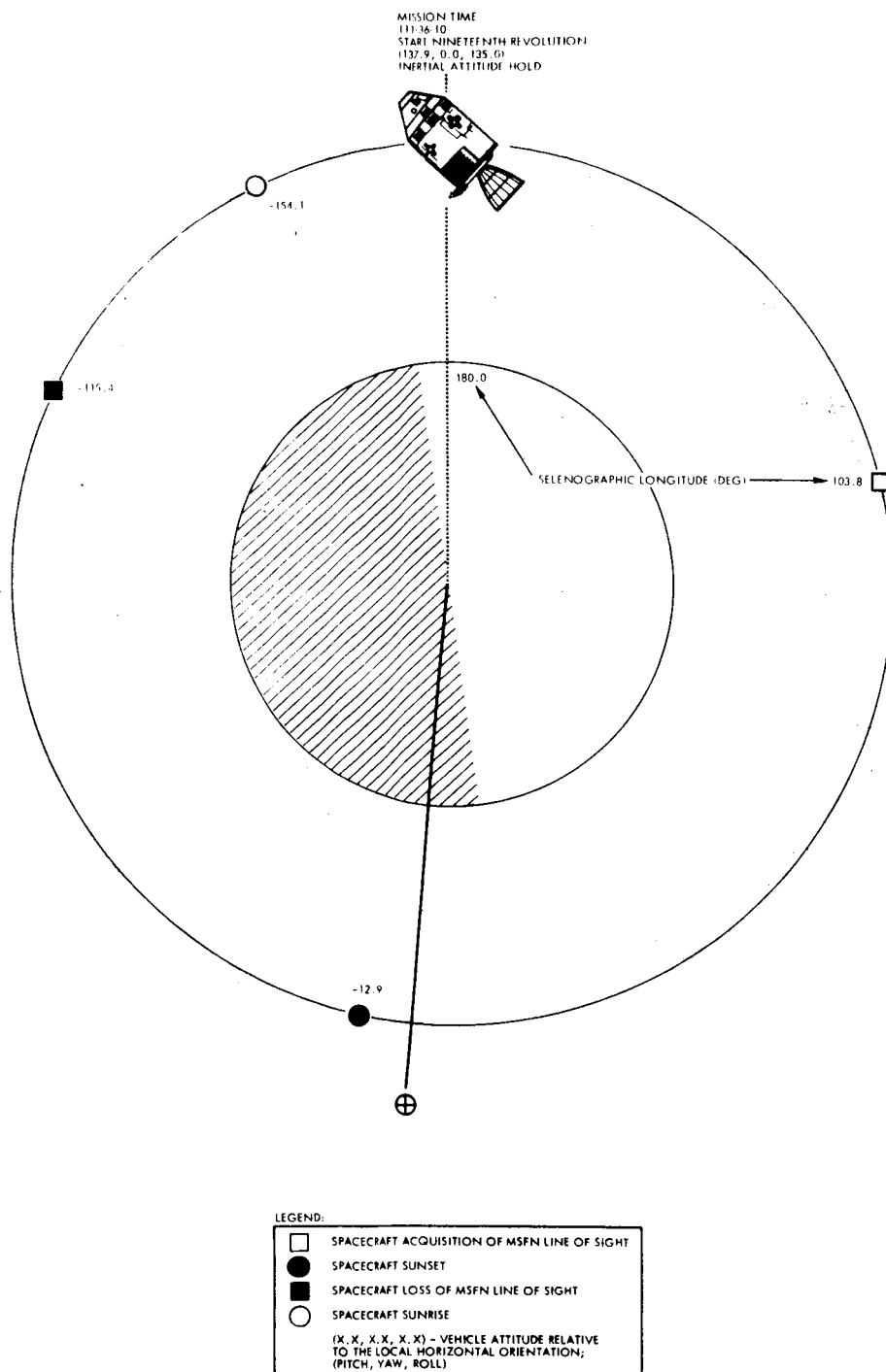


Figure 29. Nineteenth Revolution Major Events and Attitudes

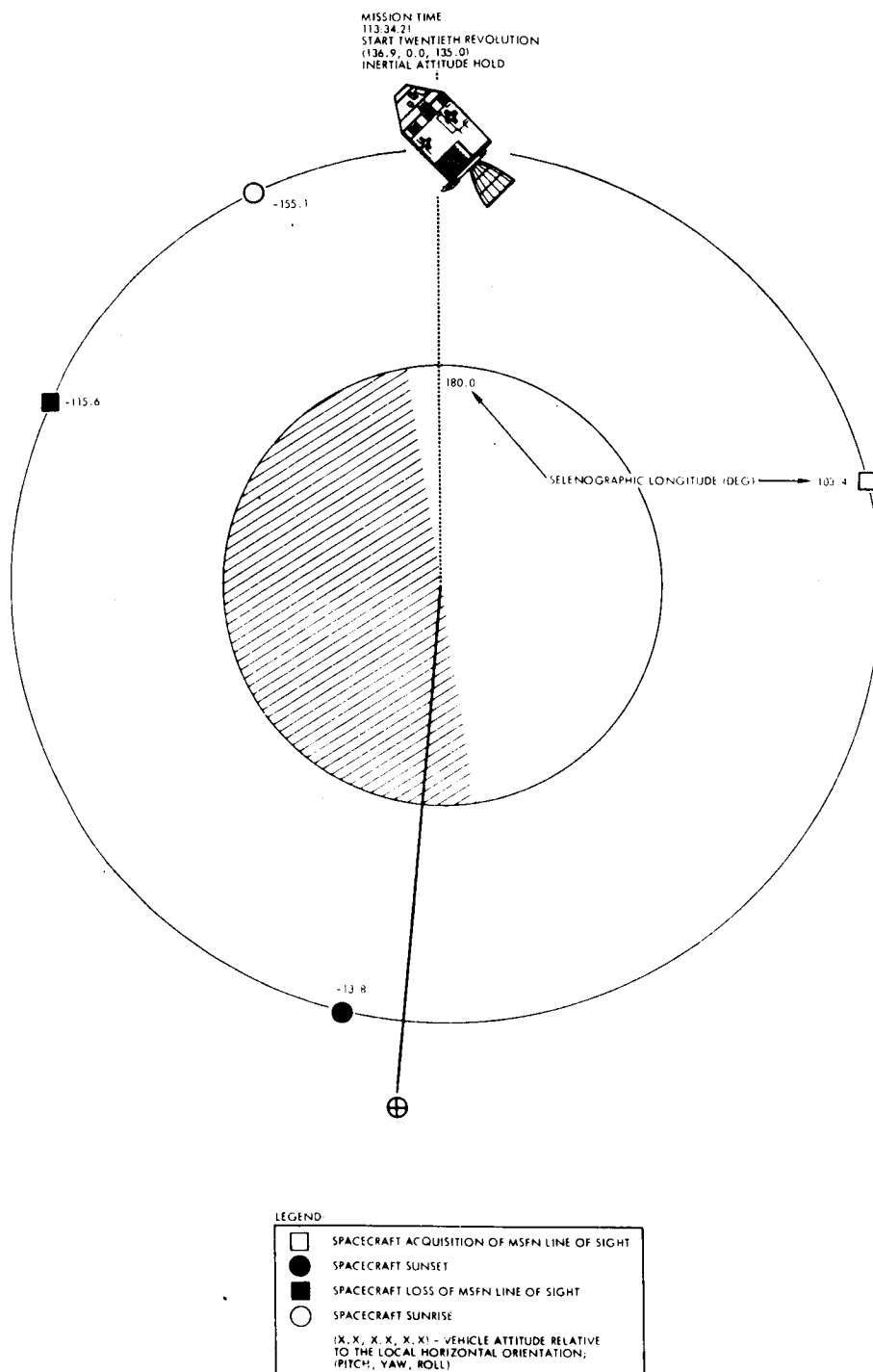


Figure 30. Twentieth Revolution Major Events and Attitudes

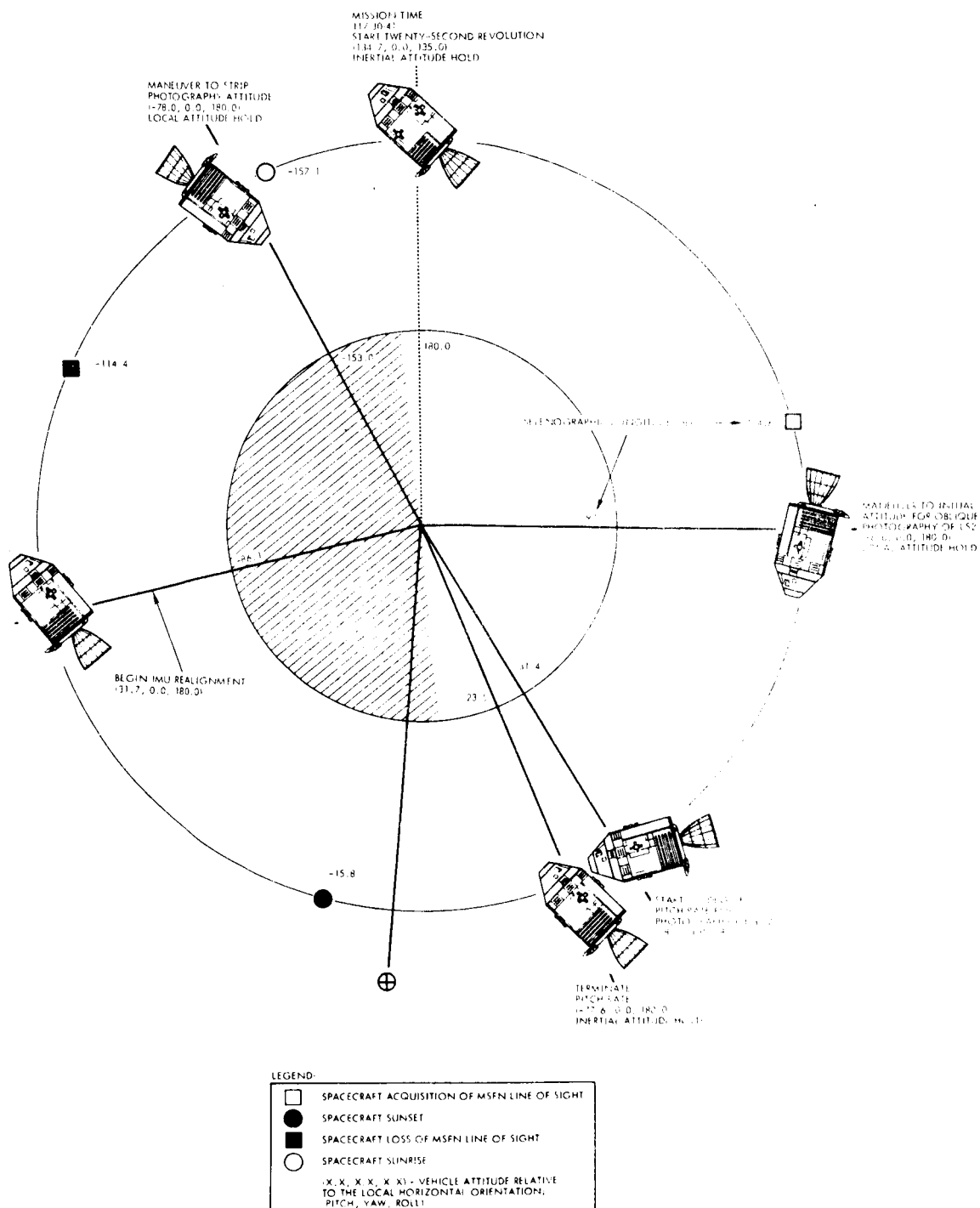


Figure 32. Twenty-second Revolution Major Events and Attitudes

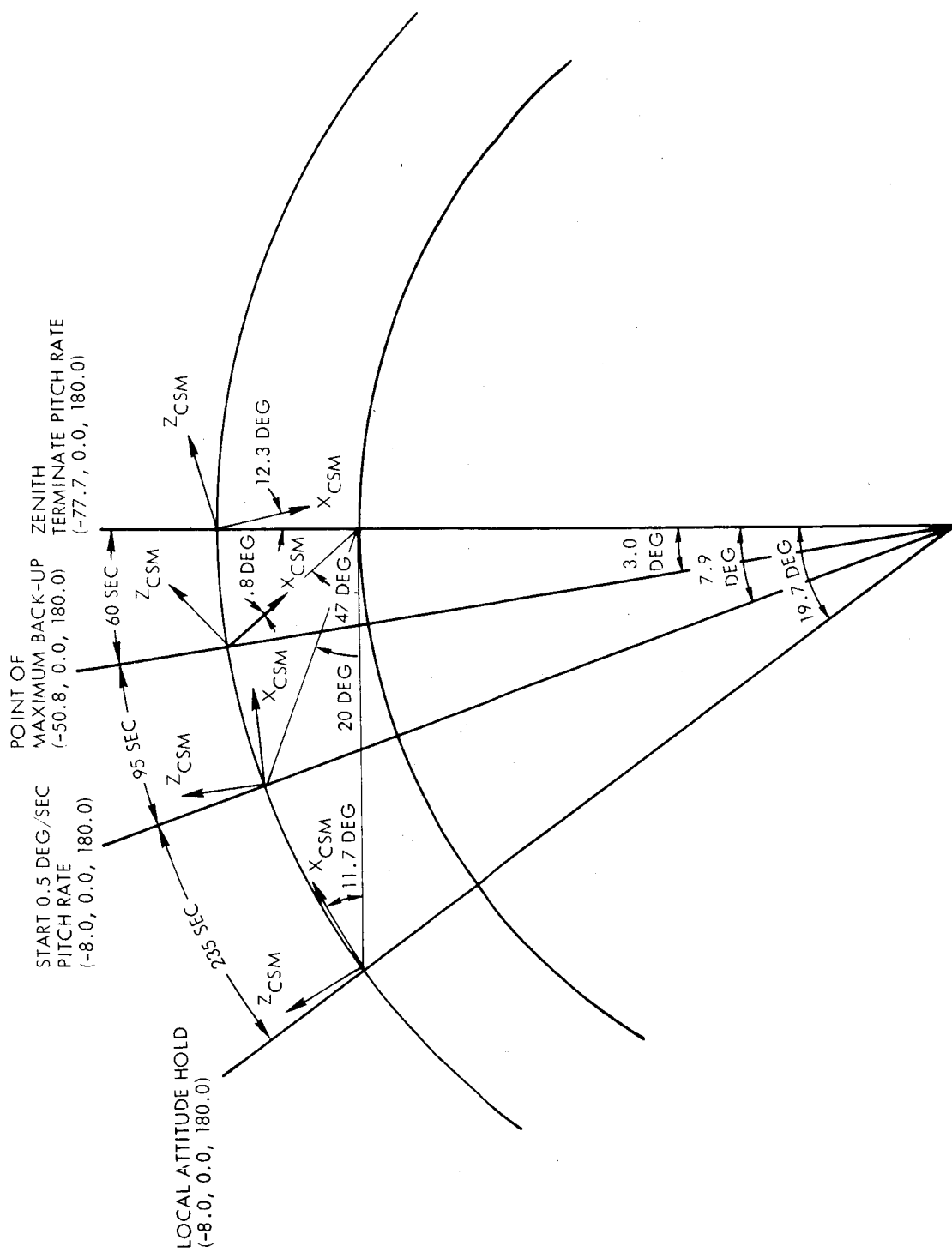
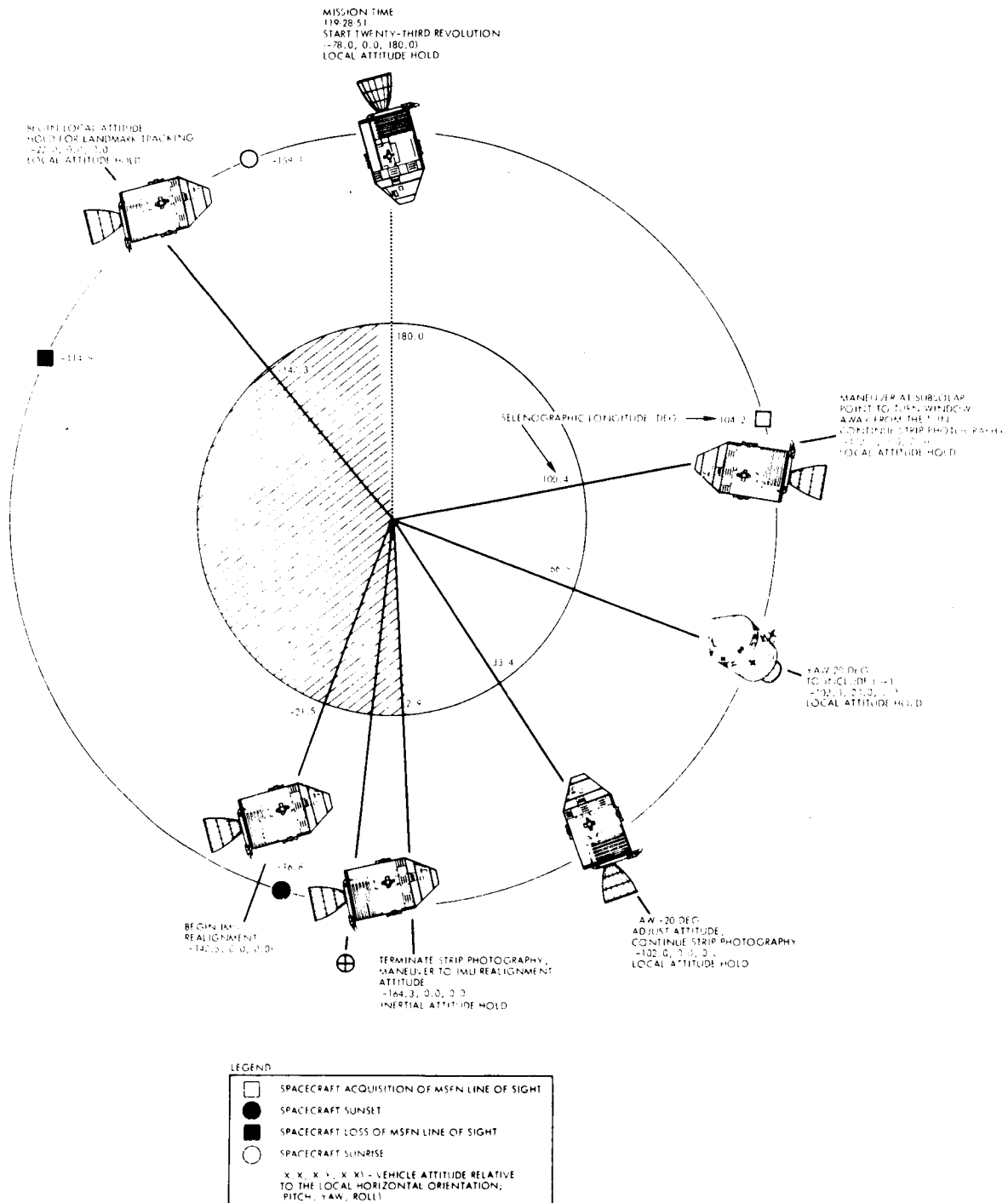


Figure 33. Oblique Photography Attitude Sequence



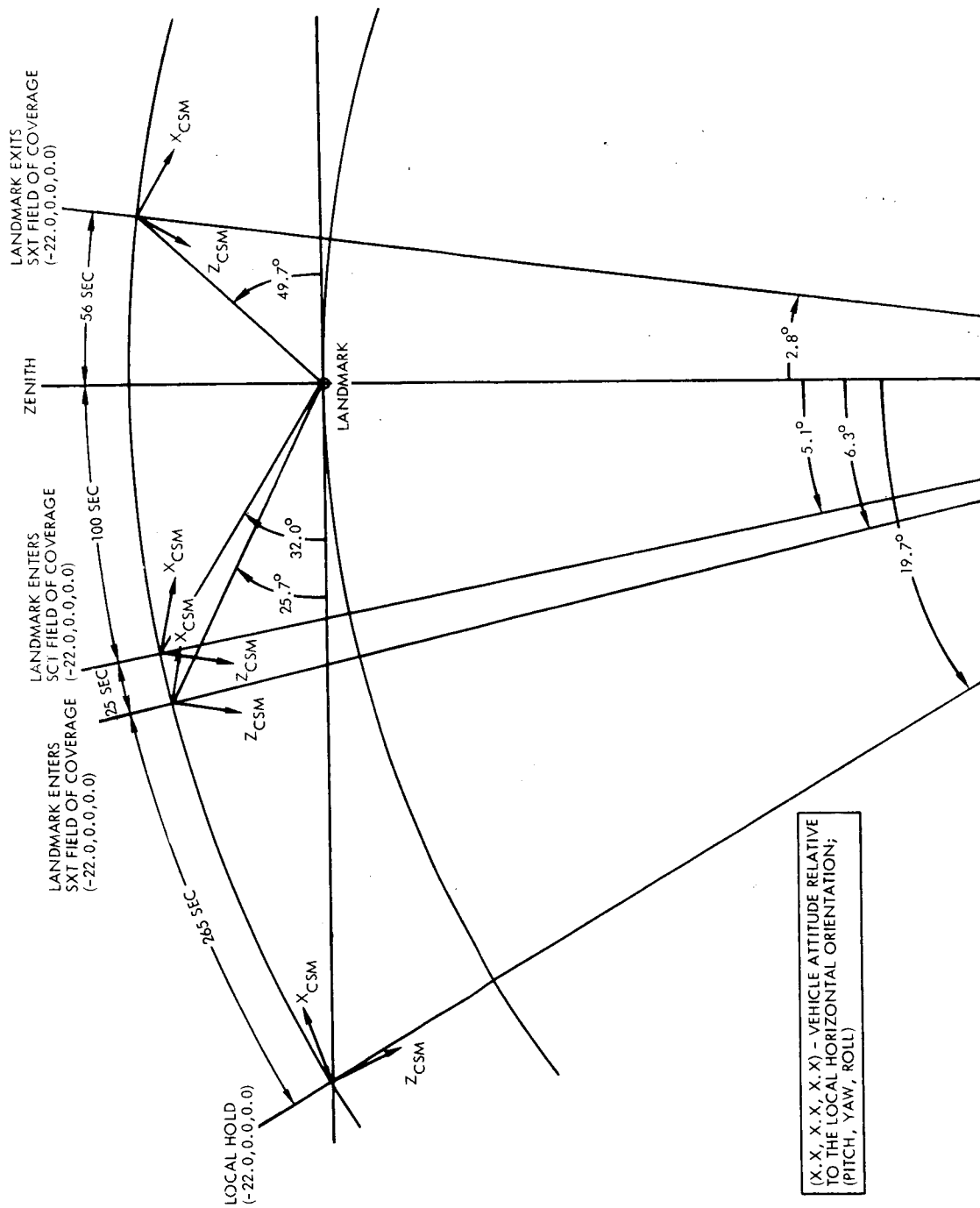


Figure 35. Tracking Geometry for Mode III Undocked Landmark Tracking

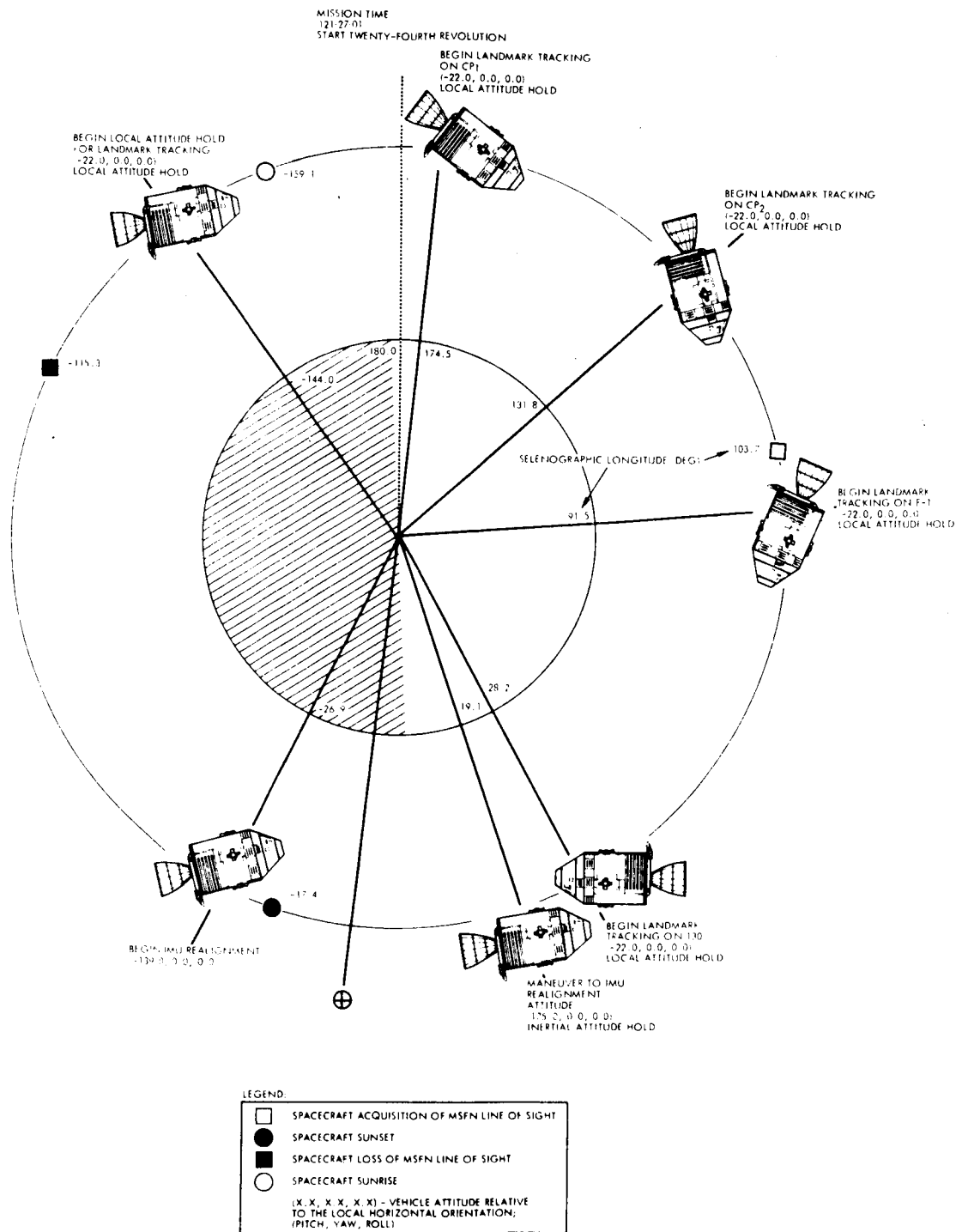


Figure 36. Twenty-fourth Revolution Major Events and Attitudes

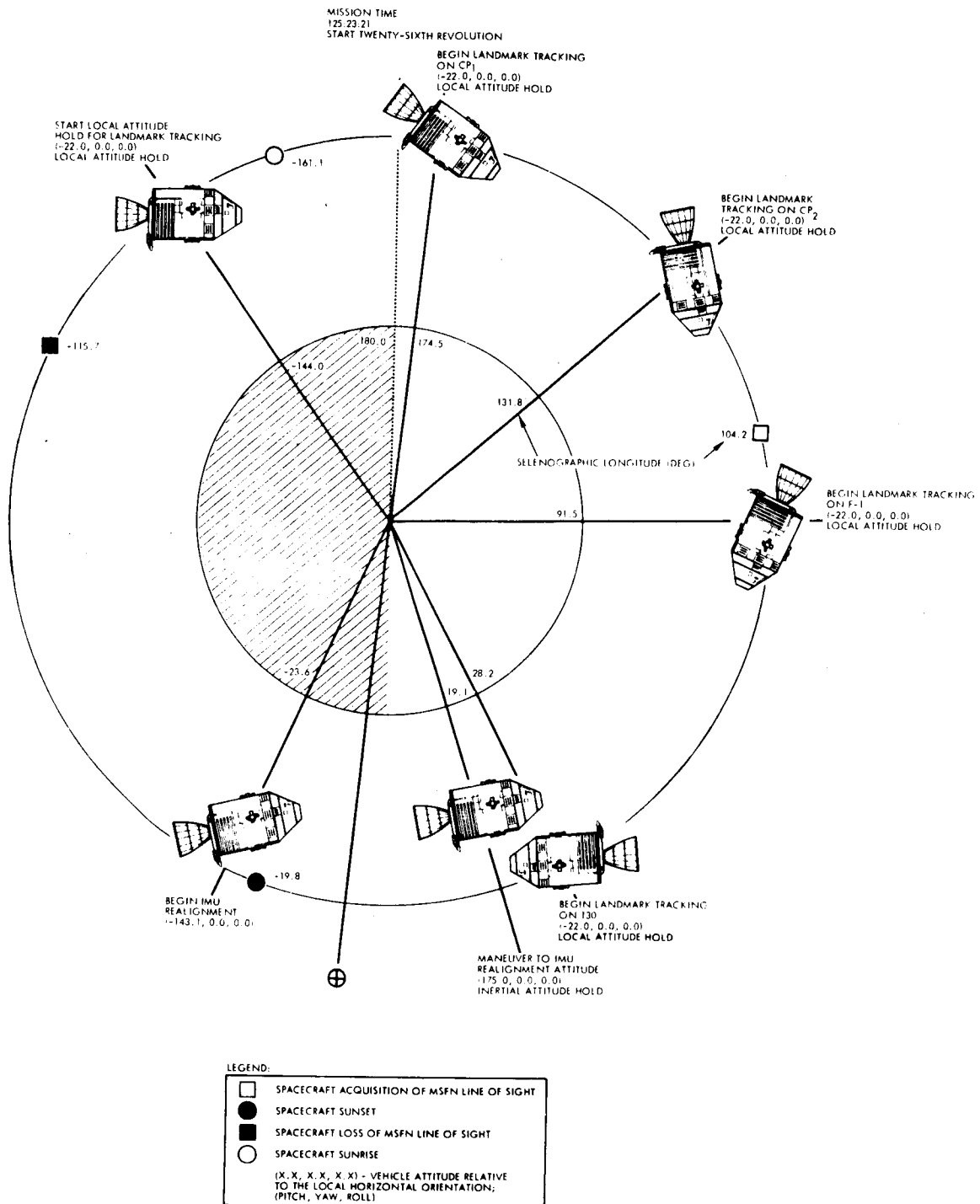


Figure 38. Twenty-sixth Revolution Major Events and Attitudes

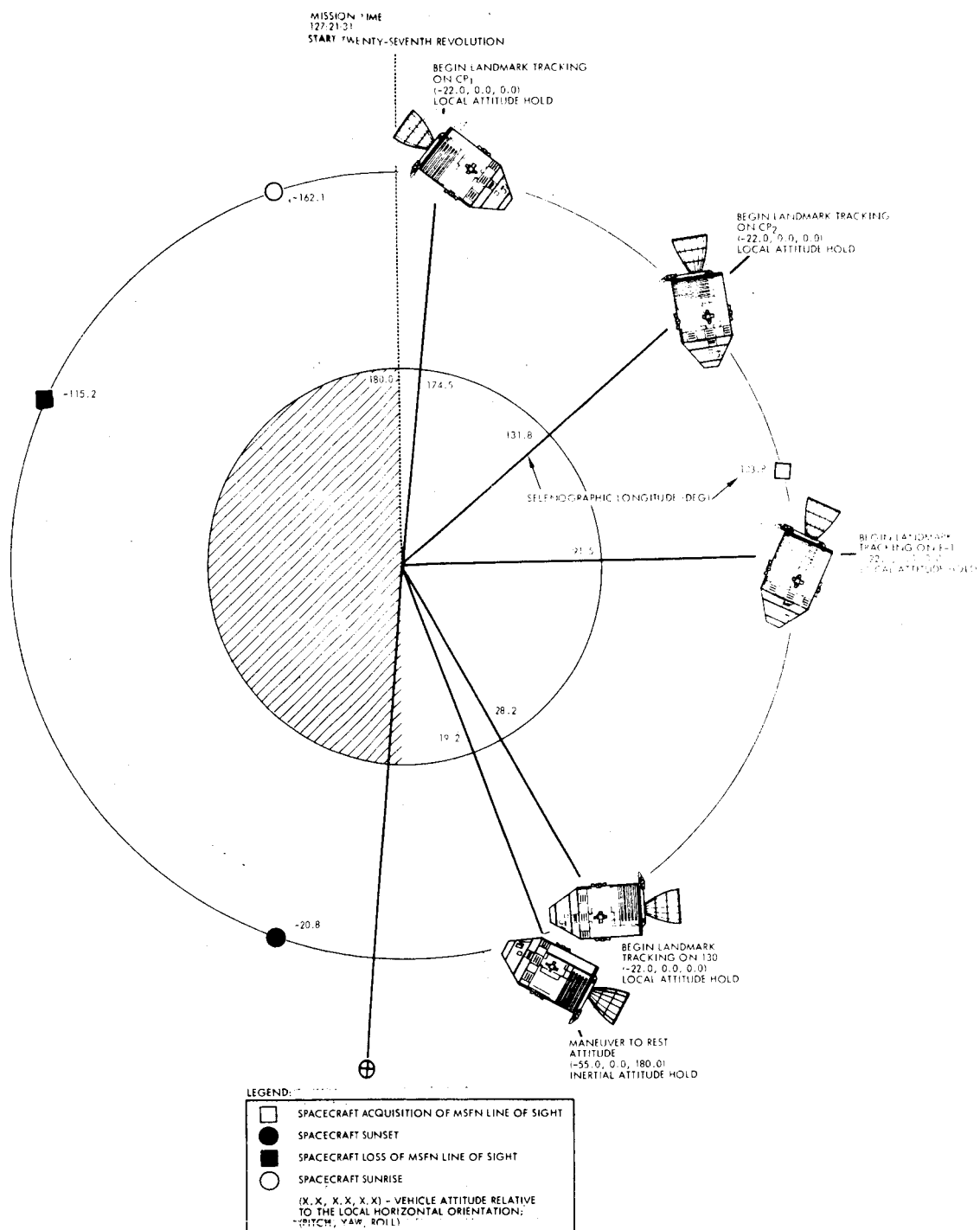


Figure 39. Twenty-seventh Revolution Major Events and Attitudes

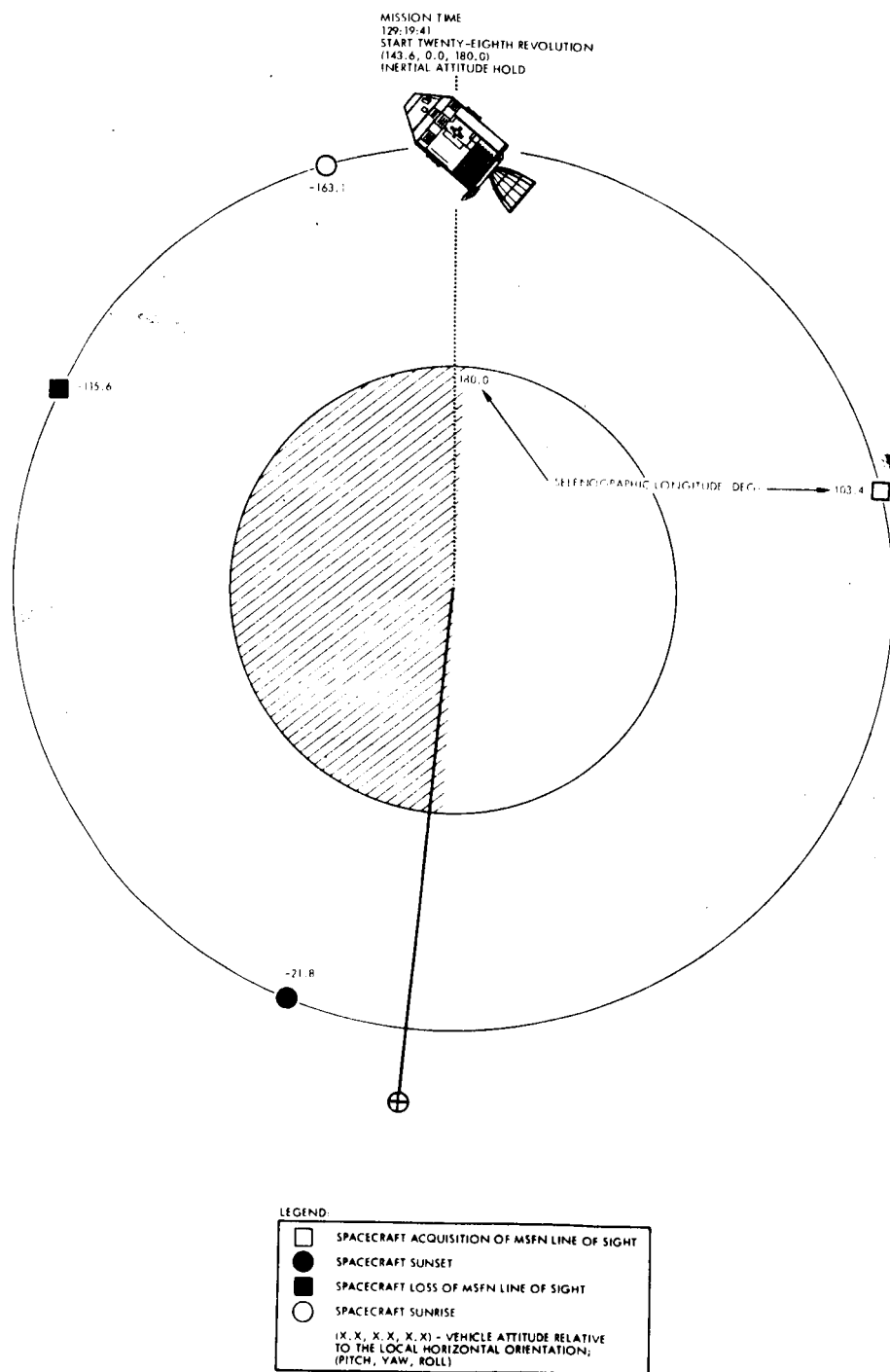


Figure 40. Twenty-eighth Revolution Major Events and Attitudes

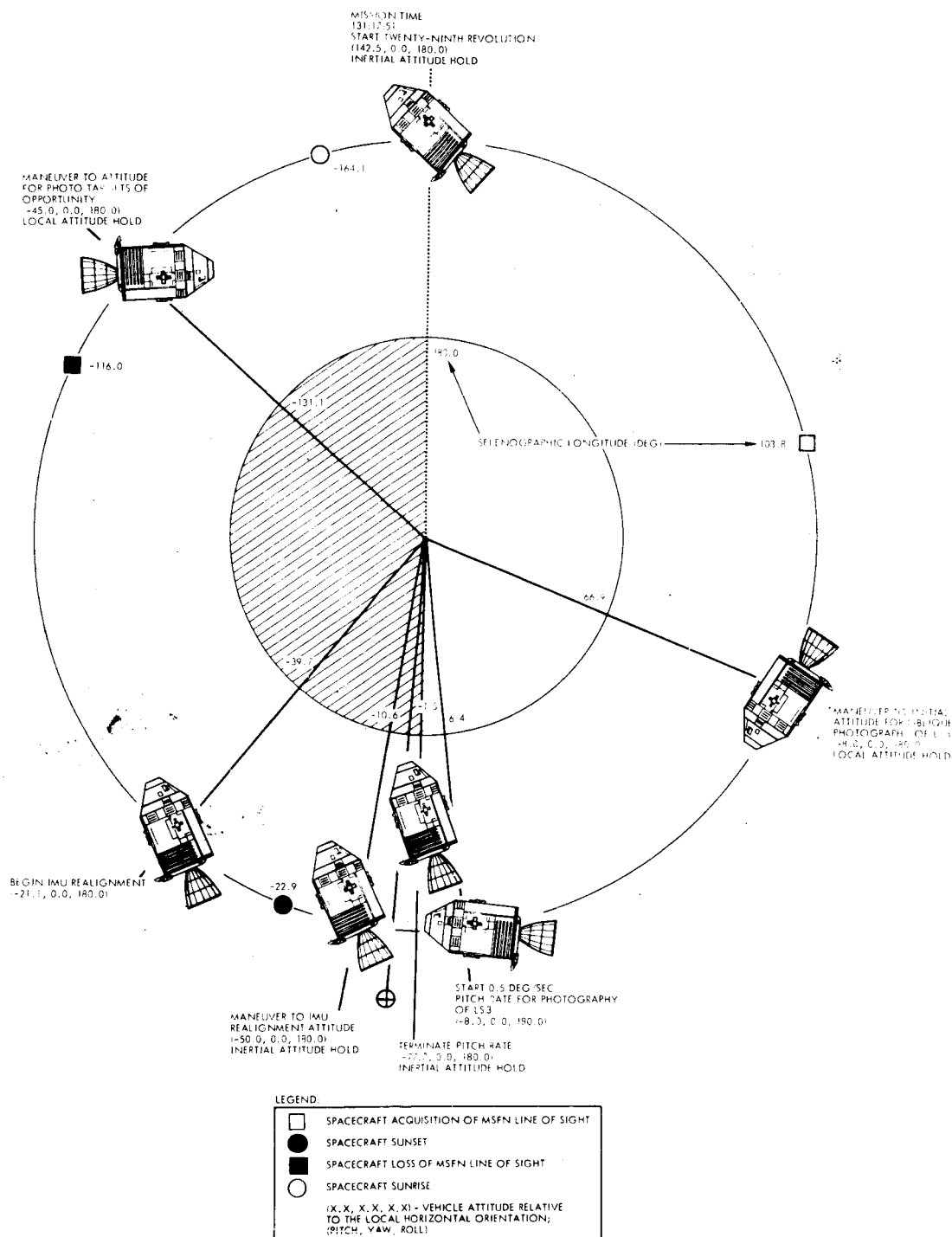


Figure 41. Twenty-ninth Revolution Major Events and Attitudes

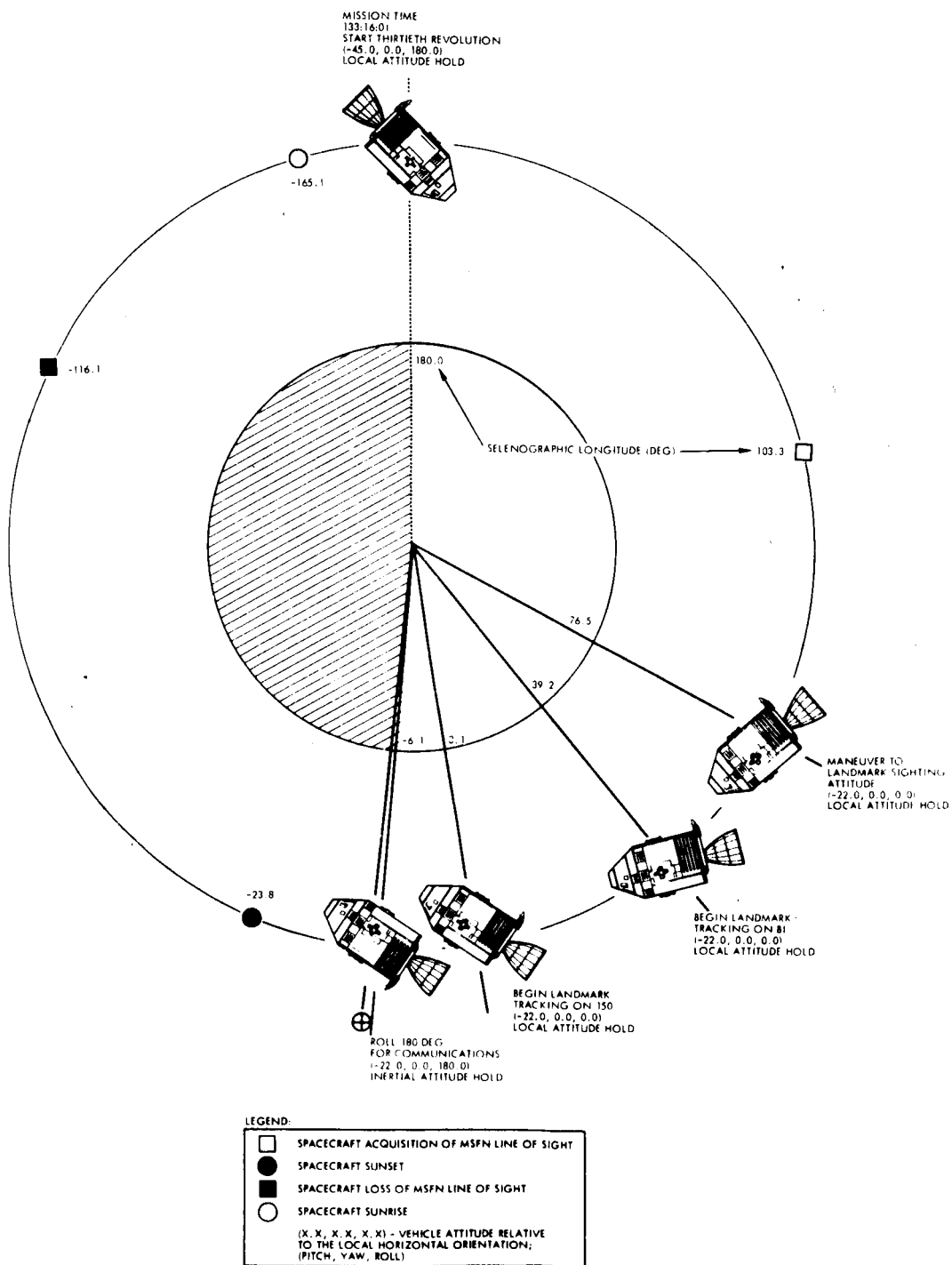


Figure 42. Thirtieth Revolution Major Events and Attitudes

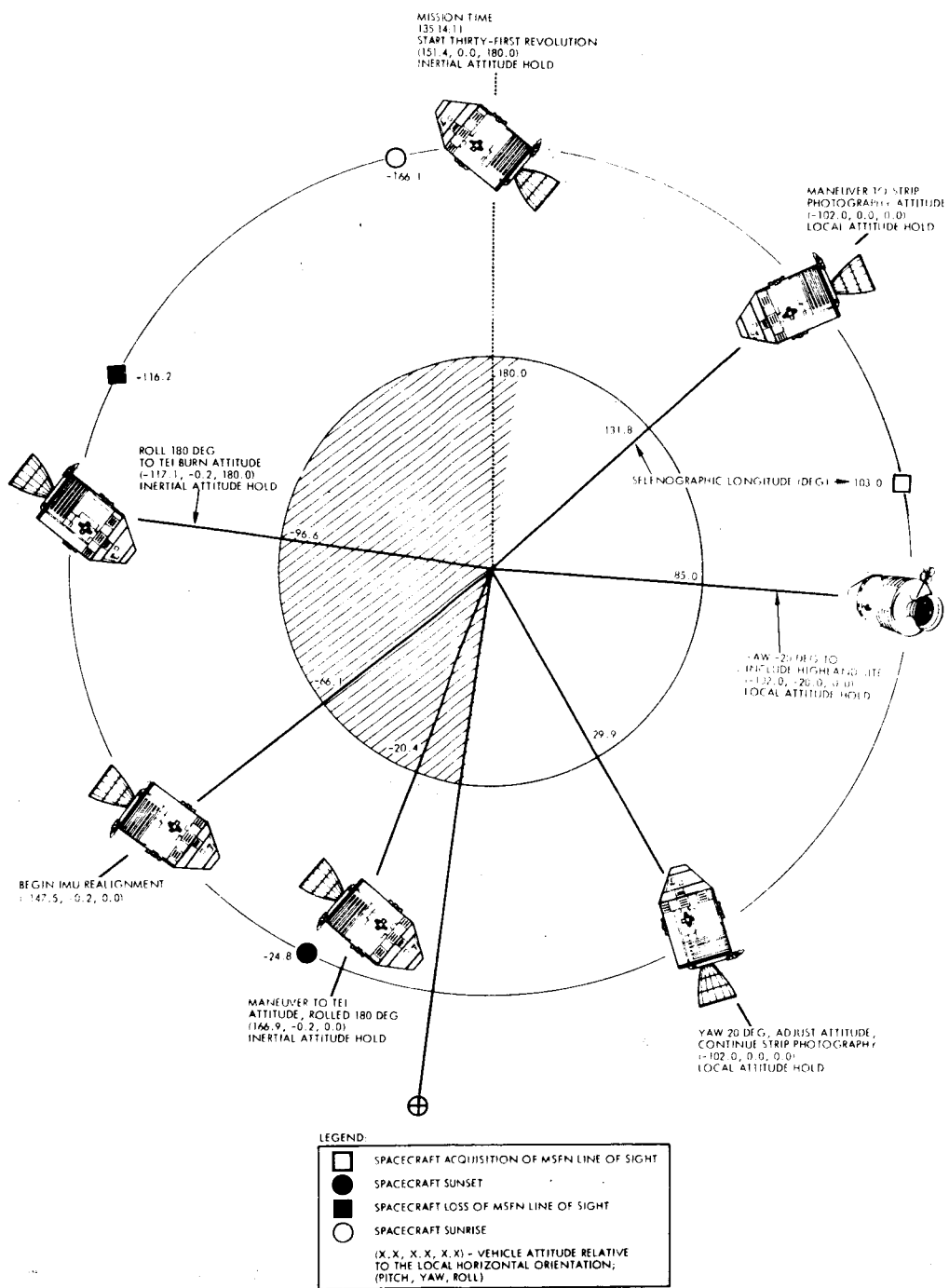


Figure 43. Thirty-first Revolution Major Events and Attitudes

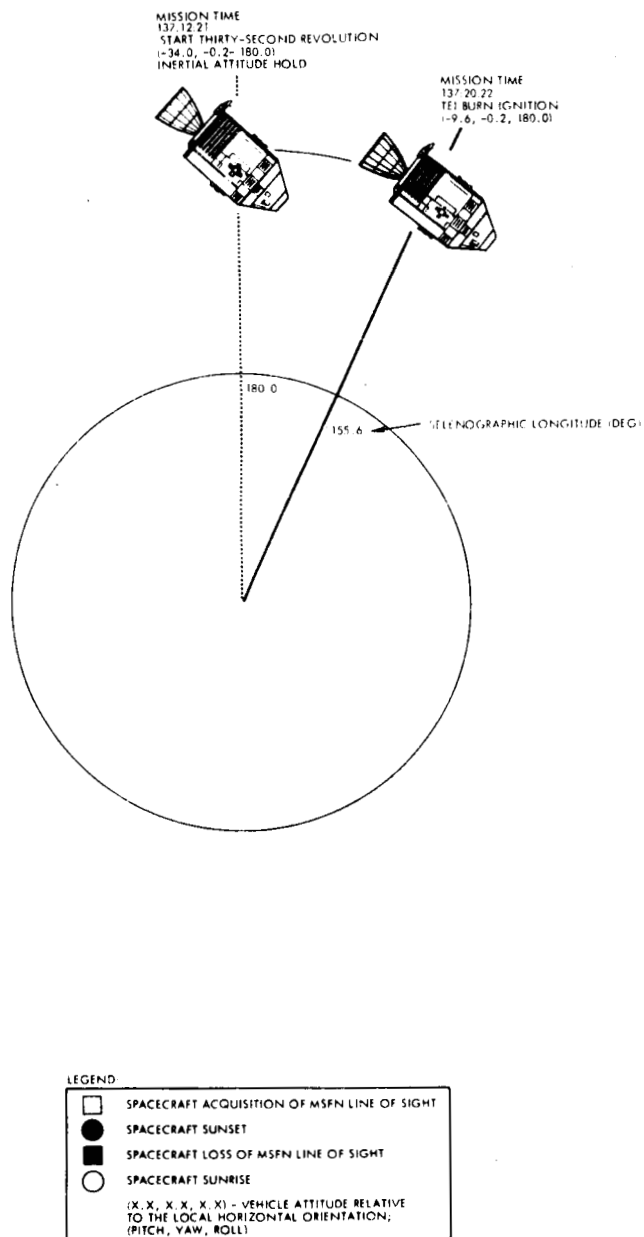


Figure 44. Start of Thirty-second Revolution to TEI Burn Ignition

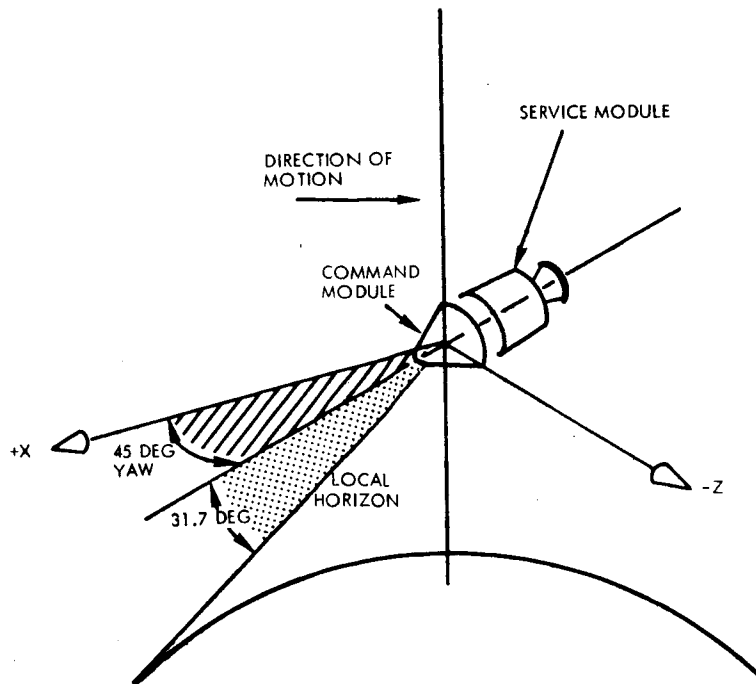


Figure 45. CM/SM Separation Attitude

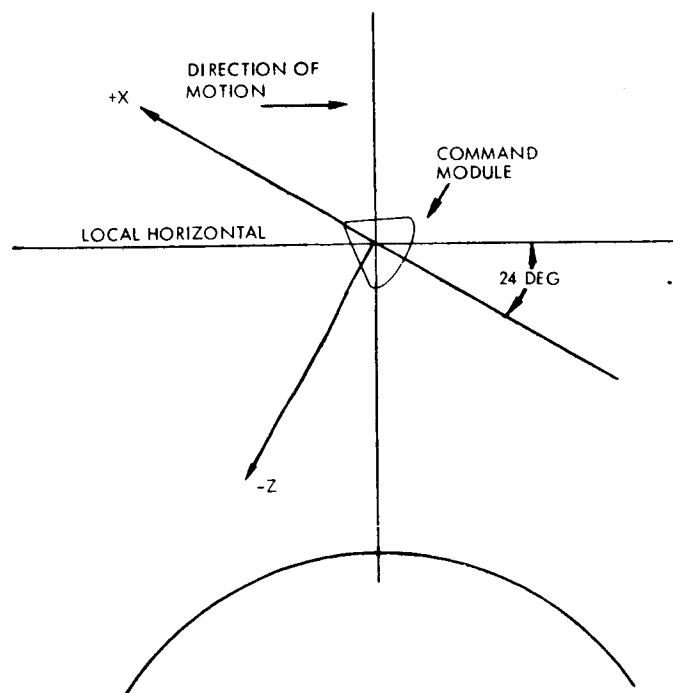


Figure 46. CM Entry Attitude



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